DSIR Land Resources Research Report 1 April 1990-30 June 1992

NEW ZEALAND
DEPARTMENT OF
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RESEARCH

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DSIR Land Resources

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Foreword

Management solutions to current major national issues such as sustainable primary production, conservation of threatened species and ecosystems, control of animal pests and noxious weeds, effluent and waste treatment and the impact of climate change depend on an understanding of the interactions between plants, animals, land and soils within the biosphere.

An 'ecological' – in its broadest sense – land management research strategy was instituted by the establishment of DSIR Land Resources in April 1990. The Division was formed by merger of Botany Division, Ecology Division, Division of Land and Soil Sciences and the Science Mapping Unit of DSIR, giving a multi-disciplinary capability for environmental research and consultancy services.

The divisional research programme has been designed to respond to national issues and science priorities and to maintain stewardship of national collections and databases relating to the land, flora and fauna. The programme is multi-disciplinary and where appropriate is collaborative with other organisations. The success of the Division is evidenced by the results outlined in this report and the recognition accorded to staff, both nationally and internationally.

On 30 June 1992 all divisions of DSIR, and the research divisions of the Ministry of Agriculture and Fisheries, Ministry of Forestry and NZ Meteorological Service were formally disestablished by science restructuring and ten new Crown Research Institutes were established. Staff of this division moved into Landcare Research New Zealand Ltd where the guiding philosophies of 'ecological' land management and integrated land use systems research will endure to the nation's benefit.

Alastair D Wilson
Director

Biosystematics and Ecology

BIOSYSTEMATICS OF PLANTS AND NEMATODES

The scientific recognition, description, classification, and naming of New Zealand's plants and animals has been going on since the arrival of Captain Cook in 1769. Even now, many new species await naming, and a lot of earlier names need checking by reference to their original collections. The classification of our organisms into groups that reflect their evolutionary history will bring new insights to our understanding of the New Zealand environment and its history.

In this programme, such studies lead eventually to the production of Floras, which describe all the plants of particular groups for the whole country. A series of Floras treating all the native and naturalised flowering plants is now almost complete, a moss Flora is in progress, and the third and final volume of a series on desmids, a group of microscopic fresh-water algae, was completed. The description and classification of nematodes, or roundworms, is also included in the programme.

Herbarium

The DSIR Land Resources Herbarium is the largest in New Zealand, containing over 540 000 plant specimens. The primary function of the herbarium is to be a database for a wide variety of botanical research. The conventional herbarium specimen is a plant which has been dried flat and attached to a sheet of stiff card. Each specimen has a label which gives its botanical name, details of where, when, and by whom a plant was collected, habitat and other information such as flower colour. Plant parts such as seeds, cones, fruits and wood fragments, some of which are preserved in liquid, are also part of the Herbarium collection.

A surprising range of information can be gleaned from a herbarium specimen. Accurate descriptions can be prepared for Floras and technical books and measurements can be made for statistical analysis. From the labels, the distribution of a species can be mapped and its habitat preferences and flowering times determined.

A major area of research traditionally associated with herbaria is taxonomy - the classification, description, and naming of plants. Taxonomy of plants of the New Zealand region is a principal part of the research effort associated with this Herbarium. Study of herbarium specimens allows taxonomists to appreciate the range of variation within species and to compare allied species. It is usually only in the herbarium that it is possible to compare all the related species of a genus in the same place, in the same state and at the same time. Loans of important specimens for research are made to other herbaria and exchange of New Zealand specimens with overseas herbaria occurs regularly.

Herbarium specimens can even be used for plant chemistry. Recently, leaves from specimens collected in known gold yielding parts of New Zealand were tested for their gold content. Voucher specimens for chemistry and other studies are important so that the correct identity of the plant can be checked should the results of the study be unexpected.

To assist in obtaining information from the Herbarium, a computer program CHIRP (Christchurch Herbarium Information storage and Retrieval Project) is being developed. All new specimens received are processed into CHIRP and labels are printed. A limited number of distribution maps and plant lists have been generated from the database. Some 1200 rare plant records have been placed on the database and made available to the Department of Conservation.

Plant identification

The Herbarium operates a New Zealand-wide plant identification service. Correct identification is an essential first step for information retrieval

Thelymitra aemula *is a native orchid which has been mis-named in the past.*

DSIR Land Resources is the authority on plant taxonomy and plant identification.

and communication about plants. Identification of weed species is particularly important for monitoring the spread of existing weeds and the establishment of new weeds. Noxious Plants Officers regularly use this service and a newsletter called *Weed Identification News* is distributed to keep them informed. To help prevent the establishment of unwanted plants in this country, DSIR Land Resources is involved in the identification of plant imports. Plants and their parts, such as seeds, are identified for forensic purposes. The identification of poisonous plants is another area of expertise. About 400 plant identifications are made each year. The main enquiries are from regional councils, environmental agencies, research organisations, and the general public.

Plant systematics

Native plants

Many large genera of native plants have not been systematically studied for over 50 years, if at all. Recent studies have begun to revise the taxonomy and unravel the complex evolutionary history of *Hebe*, our largest genus, and its relatives *Parahebe* and *Chionohebe*. Classification decisions of the past have tended to group species which were similar, rather than species which were related, so that although a large number of species clearly belong to *Hebe*, several small groups had been placed in the genus with uncertainty. A number of new morphological and anatomical characters have been discovered which more reliably indicate the relationships of these groups to the core of *Hebe* and to *Parahebe* and *Chionohebe*. A new classification, reflecting these relationships, will be proposed. A draft checklist of all the species of *Hebe* has been prepared, listing about 100 accepted species. Two unnamed species of *Hebe* have been discovered by DSIR Land Resources staff during the period of this report.

Naturalised grasses

The identification of wild grasses in New Zealand has been hampered for decades by the lack of a comprehensive descriptive treatment which includes all the recent discoveries and revisions of their taxonomy. Over recent years, steady progress has been made towards the fifth volume of the Flora of New Zealand, which will describe all the wild grasses in this country. Several precursor taxonomic revisions on major genera have been published and the main body of the text and most illustrations are now completed. This volume will be published in 1993, completing the Flora series begun in 1961.

Native orchids

New Zealand has about 100 species of native orchids found in a wide range of habitats from the subtropical Kermadec Islands to the Subantarctic Islands. At least 20 are unnamed and several others are of uncertain status. Some 25 species are considered to be threatened in the wild, and eight of these are among our rarest native plants.

A complete revision of native orchids has been initiated in collaboration with Australian orchid specialists, and with the added support of the New Zealand Orchid Council, the Australian Orchid Foundation, and several local orchid societies. The chromosome numbers of most of the species have been determined from plants grown at Lincoln or in the wild, and this work has proven invaluable to the revision and also shed much light on the origin and history of New Zealand orchids. A Catalogue of New Zealand Orchids is in the final stages of preparation. Future work will centre on the description of new species and the biology of orchids relevant to their conservation or cultivation.

Native conifers

Native conifers are among the better known plants of New Zealand and occur throughout the country in a wide range of habitats. They vary in size from the massive kauri to the dwarf pygmy pine, said to be the smallest conifer in the world, and include many species such as totara, matai, and kahikatea, formerly exploited for their timber values. Conservation of these conifers as an important part of our nation's heritage.

Until recently, 18 species were recognised and assigned to five genera within three families. However, recent revisions have resulted in the reassignment of nine species to five different genera of which three are new. Further re-classification is necessary and the additional new species and genera need to be described.

Mosses

Mosses are an important part of natural forest ecosystems and some such as sphagnum have many commercial uses. New Zealand has about 500 species of moss and work is underway to document and describe these species for publication in a moss Flora. Several new species, either undescribed or previously unknown to occur in New Zealand, have been identified. Moss collections held by the Natural History Museum in London are being examined and catalogued to clarify the naming of New Zealand species.

Desmids

Desmids are microscopic green algae that live in freshwater lakes, ponds, bogs and swamps. Although most desmids are single cells, they occur in a variety of shapes and can have highly patterned cell walls. Most desmids require clean unpolluted water and so their presence or absence can be used to monitor changes in water quality. Accurate identification is critical for this purpose. The *Flora of New Zealand Desmids* contains illustrated descriptions of the 700 taxa found in New Zealand and keys for their identification. The third and final volume of the series will be published in 1992.

Lichens

Since the *Flora of New Zealand Lichens* was published in 1985, many significant changes in the naming and classification of lichens have occurred overseas. A lichen checklist which incorporates new names and arrangements is being produced by the Flora author, Dr David Galloway. This, when used in conjunction with the Lichen Flora, will provide up-to-date identification and reference material for over 1000 New Zealand lichens.

Wood anatomy

Fragments of wood, whether they are intact, decayed, sawdust, fossilised or charcoal are important in many kinds of investigation. Forensic evidence can rely heavily on the accurate identification and sourcing of wood fragments at the crime scene. Research on vegetation history often requires wood from swamps, glacier sites and buried forests to be identified. Archaeological studies are assisted when wood from excavations or artifacts can be identified. The identification of wood is a complex and specialised skill essential to all these applications. DSIR Land Resources identifies over 100 wood samples each year, mainly for other Government Departments.

The basis for wood identification is its anatomy, i.e, its microscopic structure. The size and arrangement of wood cells and cell wall patterns are unique for each species, although some may be difficult to distinguish. Wood anatomy studies involve describing the structure of wood in three dimensions, i.e., the transverse, tangential and radial planes. This information can be used to clarify taxonomic relationships between species as well as to assist identification. Wood of many families of native trees and shrubs has been described. Descriptions of three families, Cunoniaceae, Loranthaceae and Proteaceae have been completed during the period of this report.

Chromosomes

Chromosomes are the microscopic carriers of genetic information. Plants are able to tolerate changes in the number and structure of their chromosomes and still remain viable. Spontaneous chromosome changes can lead to new plant forms and, over long periods of time, the evolution of new species. Deliberate chromosome changes can be induced for plant breeding purposes and are used in the development of ornamentals and crops.

Plant chromosome studies are useful for determining taxonomic relationships between and

within plant groups. Chromosome counts and karyotypes were made to clarify the classification and naming of species belonging to genera of *Clematis, Dracophyllum, Hebe, Leptospermum* orchids, and *Raoulia.*

Pollen and seeds

Pollen contains the male reproductive cells and is produced in vast quantities by many flowering plants. At certain times of year these minute particles occur in large concentrations in the air and some types cause hayfever and allergies. Identification of pollen preserved in peats, lake sediments and ancient rocks, allows reconstruction of past vegetation and provides information about how climates have changed. Pollen analysis can be a useful tool in forensic science and for the sourcing and quality control of honey. The text and photographs for a Pollen Atlas of New Zealand Dicotyledons has been completed and will probably be published in late 1992 or early 1993. This identification manual describes and illustrates the major types of pollen grains produced by native plants.

The correct identification of plant seeds assists many research areas, for example, in analysing mammal or bird diets from gut or gizzard contents or faeces, determining past plant distributions from deposits in bogs or soils and determining food and crop plants at archaeological sites. There are applications for forensic science and the identification of seed contaminants in imported consignments is important in preventing unwanted weeds entering New Zealand.

Seeds provide many characters important to plant identification and classification. An illustrated guide to seeds or Seed Atlas for native plants is being prepared. The descriptive text, keys and captions to accompany the first 20 photographic plates have been written.

Flowering plants of New Zealand - *Colin Webb, Peter Johnson, and Bill Sykes*

In 1990, DSIR Land Resources published *Flowering Plants of New Zealand,* a popular account of New Zealand's major flowering plant families. This book was a major DSIR contribution to the 1990 celebrations and received a ministerial launch at the Beehive. A copy was donated to every secondary school library in the country.

Plants with flowers are the most important part of the world around us. They dominate the earth's vegetation, and provide most of the essentials for human life. The flowers themselves are a key to recognising the diverse families which have evolved independently, each with its own properties, uses, and appeals. New Zealand has a high level of endemism among its plants as a consequence our early separation from Gondwanaland. Although no flowering plant families are unique to New Zealand, our representatives are often specialised in unusual ways that make them difficult to recognise as members of their families.

The book illustrates, in full colour, 52 families and describes their distinguishing botanical features and family floral characters. For each family, key genera, overseas representatives of special interest, and botanical statistics are included.

Nematode systematics

Plant and soil nematodes are small, worm-like animals whose abundance is often measured in millions per square metre. A given site may yield 30 different species. While some forms reduce plant growth and cause economic crop loss others benefit plant growth through increasing the cycling of plant nutrients. Nematodes are important indicators of soil health and can be used to monitor reactions of soil to environmental disturbance.

The nematode fauna of the New Zealand region is very poorly understood. Taxonomic studies to characterise the native nematode fauna also contribute to understanding of the ecological and biogeographic relationships of the New Zealand soil biota. This work is carried out in parallel with assessments of the contribution of nematode populations to soil processes in natural and disturbed ecosystems.

Surveys of three plant feeding genera from managed soils in New Zealand were completed and a new species was described from forest subsoil in the Orongorongo Valley. Recent collecting has concentrated on plantation forests and native vegetation. Taxonomic studies of several plant-feeding and bacterial-feeding groups are in progress.

FLORA OF THE COOK ISLANDS

The goal of this programme is to publish a flora of the Cook Islands. A flora is an identification manual covering all the plants of a particular region and is a source of authoritative botanical knowledge. Floras contain information about botanical and common names, plant morphology, distribution and habitat, and provide precise and detailed botanical descriptions for each species. Flora writing is based on field work and studies of herbarium specimens, taking many years to complete. Field work on all the islands of the Southern Cooks has been completed and the herbarium at Lincoln holds the largest and most comprehensive collection of Cook Island plants. The other major collection of Cook Island plants in Honolulu have been studied.

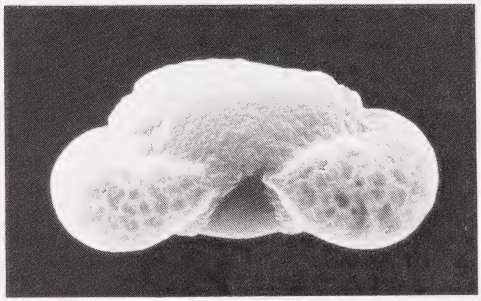
A complete annotated checklist of Cook Island plants, which will form the framework for writing the flora, has been produced. The checklist, as well as listing the correct botanical name for each species, also includes other botanical names used in the past and the Cook Island and English names. The checklist contains information on the distribution

of each species within and outside the Cook Islands. The habitat of each species, whether it is abundant or rare and its status in the Cook Islands, i.e., whether indigenous, naturalised or only found in cultivation is also noted in the checklist.

VARIATION IN NEW ZEALAND TEATREES

Several large plantings of New Zealand species of manuka (*Leptospermum scoparium*) and kanuka (*Kunzea ericoides*) were established at Lincoln to determine the nature of genetically based variation. Results show widespread variation in growth, habit, flowering, cold tolerance, resistance to pests and diseases and other characteristics.

A study of the variation of cold tolerance of New Zealand populations of *L. scoparium* was undertaken. This involved a cooperative programme with the Laboratory for the Improvement of Trees and Shrubs at INRA, Angers, France. Populations of manuka from a range of latitudes and altitudes in New Zealand showed marked differences in frost damage when subjected to extended periods of freezing in the 1990-91 winter at Angers. Manuka from montane sites of the South Island were largely undamaged by temperature as low as -12.5°C, a tolerance level much greater than previously demonstrated. This reveals the potential for selecting cold hardy cultivars of *L. scoparium* for ornamentals in cooler temperate regions. These observations also further understanding of the genetic basis of adaptation of native and introduced plants to regional climates in New Zealand.



A pollen grain of matai (Podocarpus spicatus).

Cultivar collections and selection

The experimental gardens at Lincoln contain collections of named cultivars from several genera of native plants, most importantly, *Phormium, Hebe, Coprosma, Pittosporum,* and *Lophomyrtus*. These collections are used to prepare cultivar checklists and are a source of material for selection of new cultivars. There is often confusion surrounding

Differences in flower size and arrangement arise when manuka and the Great Barrier Island kanuka are crossed (second from left).

names of cultivars in these genera and inadequate information about their origin. The checklists of *Phormium* and *Cordyline* cultivars published in 1991 are a significant step toward resolving some of these problems. Assembling cultivar collections at one site overcomes the variation which can arise from growing a cultivar at different locations.

A number of plants have been identified as sufficiently distinctive and attractive to be considered for development as ornamentals. The first cultivar arising from this programme was *Leptospermum* 'Christmas Star' selected, as a compact shrub form with distinctly large red flowers, from the attractive Australian species *L. spectabile*. A more recent selection is based on a wild hybrid of *Hebe odora* x *H. armstrongii*. This is called *Hebe* 'Karo Golden Esk', and is being propagated and marketed by a major New Zealand producer of ornamental plants. The name 'Karo' is an acronym of "known and recorded origin" and will be applied to further cultivars developed at Lincoln. Several other selections are being assessed by New Zealand and overseas propagators with the prospect of contracts for the multiplication and sale of these plants. Interspecific crosses are being made in *Hebe* and *Leptospermum*. There are early signs that new attractive ornamental cultivars will arise from the resulting hybrids. The discovery that large flower size in some cultivars of *Leptospermum scoparium* is related to an increase in the number of sets of chromosomes (ploidy level) up to the tetraploid level in *Leptospermum* 'Keatleyi' and the existence of an intergeneric hybrid between *L. scoparium* and the Great Barrier Island endemic, *Kunzea sinclairii*, point the way to exciting possibilities for further improvements in the ornamental use of teatrees.

ETHNOBOTANY - STUDIES ON MAORI AND EARLY EUROPEAN PLANTS

Ethnobotany is the study of the way people use plants and their products before commercialisation. It is important to conserve the biological diversity of plants that have been used in the past by Maori and early European and to retain the traditional knowledge about these plants in a culturally appropriate way.

DSIR Land Resources holds a computerised database called Peopleplants which contains information, from both published and unpublished sources, about plants and their uses traditional to Maori, Pacific Islanders and early Europeans. As this database has grown in size, it has been divided into several files to enable more efficient searching.

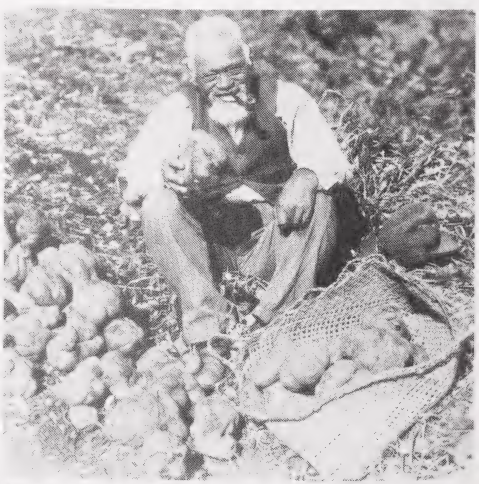
In collaboration with Pu Hao Rangi Maori Trust, a concept plan or resource document for the development of a national ethnobotanical garden in Auckland was produced. This document combines basic information about plants used by Maori, particularly kumara, and the existing living collections required to establish Te Wao Nui A Tane - A National Ethnobotanical Garden. In 1991 a Steering Committee was set up with representatives from Pu Hao Rangi, DSIR, Department of Conservation, Manukau City Council, and Auckland Regional Council to further the plans for this kaupapa Maori garden.

A living national collection of 68 traditional Maori flax *Phormium* varieties, based on the Rene Orchiston collection and other cultivars believed to have been used by Maori weavers, is maintained. This collection is located at Havelock North and Lincoln. When the plants are large enough to be divided, portions are given to weavers for planting at their own marae. Ornamental cultivars of *Phormium* are also grown at Lincoln.

DSIR Land Resources was also involved in the Inter-Institutional Linkages Programme, a cooperative programme between New Zealand and the ASEAN countries funded by The Ministry of External Relations and Trade. This programme seeks "to develop the cultural, technical and developmental aspects of regional floras" and to establish sustainable linkages between ASEAN and New Zealand institutions.

BIODIVERSITY AND THREATENED ANIMALS AND PLANTS

The majority of animals and plants native to New Zealand are unique and many groups have distinctive features that reflect their long isolation from plants and animals on other land masses. This programme investigates the factors that control the diversity and relative abundance of selected native plants and animals, with an emphasis on those species with limited or declining distributions. Our goal is to improve understanding of New Zealand's unique animals and plants and to provide



Kumara is a plant of great cultural significance to Maori (photo: Northwood Collection, Alexander Turnbull Library).

information for environmental management, conservation of genetic resources, and the preservation of our natural heritage.

Native vegetation

Tree distribution and climate change

Climate changes during the Pleistocene glaciations, which began about 2.5 million years ago, had a major impact on the distribution of tree species in New Zealand. During the last periods of intensely cold climates (25 000-15 000 years ago) most forest plants were reduced to small remnants south of the Waikato Basin. Refugia for tree species in the North Island were extensive while most species in the South Island survived only in small isolated stands. New Zealand climates warmed rapidly between 18 000 and 10 000 years ago. Reconstruction of the changes in distribution of selected tree species, using the pollen record, suggests that most tree species occupied their present range within a few centuries of this climate warming. Results of this study and a parallel investigation of the climate zones occupied by many evergreen broadleaved species in New Zealand, have provided a clearer understanding how our tree species respond to climatic change.

Vegetation patterns

New Zealand has several regions where there are many local endemic species. These "hot spots" of biodiversity are of special interest because they provide an opportunity to examine the different factors that cause species-rich areas. Two such areas have been examined in detail - western Nelson and the Waikato Basin. The mountains and valleys of western Nelson contain a wide variety of rock types along a major rainfall gradient. Differences in vegetation types among the mountain ranges largely reflect the presence of calcareous rocks and the annual rainfall. However, some local distribution patterns remain unexplained. In the Waikato, surveys of plants growing on the local hills indicates that differences in plant composition are largely due to habitat diversity, particularly the availability of sites too wet or too dry to support tall forest.

Another approach has been to document in detail the habitat occupied by species throughout their ranges. Beginning in Westland, the distribution of plant species, that are either clumped or have marked gaps in their distribution across the region, is being mapped. The reasons for the present distribution patterns of these species will be assessed from information gained from studies of their biology.

Threatened plants

New Zealand has many plant species with very limited distribution. Biological and ecological studies of representative examples of these species will assess the main factors responsible for their local occurrence. A study of water relations in the threatened Canterbury shrub, *Helichrysum dimorphum*, over the 1991-92 summer shows that the species occupies a very restricted zone in the landscape, determined largely by the plants ability to cope with water stress.

Plant dispersal and reproduction

Fleshy fruits are common among New Zealand plants and are usually eaten by birds. The range of different features found in fruits and their relative importance in the dispersal of the fruits was investigated. Research on the different fruit features in the genus *Coprosma* has revealed that red and black fruits are more conspicuous than the other fruit colours, such as white and blue. The fleshiness of fruits increases at higher altitudes but less so in the brightly coloured fruits. An experimental study in which birds were presented with intact and modified fruit showed that birds only take unblemished fruit, avoiding those with punctured or marked skins.

Some species of plants have both a male and female form. The vegetative and reproductive behaviour of such sexually dimorphic species was investigated in two recently completed long-term studies. Breeding experiments with the native climbing umbel, *Scandia geniculata*, showed a surprisingly simple mechanism of sex inheritance, probably controlled by one gene. Like many other dimorphic species, male progeny of *Scandia geniculata* flowered earlier than their female counterparts. In the Russian dimorphic umbel, *Trinia leiogona*, there was no difference in age at first flowering for male and female offspring. However, progeny of female parents are larger, possibly because female seed results from outcrossing.

Native animals

Fur seals

New Zealand fur seal populations are recovering from massive exploitation last century. In the last few years their breeding distribution has spread north and has now reached the Cook Strait region. However, the size and dynamics of the present populations are poorly known and this is fuelling the controversy regarding the fisheries by-catch. The population and breeding status of fur seals in the Nelson Bays and Marlborough Sounds region are being studied to establish an accurate baseline dataset against which future natural or human-induced trends can be quantitatively assessed.

Presently four breeding colonies have been identified between Whanganui Inlet and Stephens Island and a few others probably occur further east. Current annual pup production is in the range of 200 to 500. Further research involving marking of pups born in Tasman Bay is planned to study recruitment and other aspects of the population

Giant weta (Deinacrida *"maungakoura") from the Kaikoura Ranges.*

dynamics at the northern front of the fur seals present breeding range.

Kiwis

It is a paradox that so little is known about kiwis when they are probably New Zealand's best known bird. Their taxonomy has been debated, without resolution, for about the last 140 years, and even basic information on their distribution and abundance is still incomplete. Several mountainous areas of the South Island were surveyed in order to learn more about the distribution and status of great spotted kiwis, the largest of New Zealand's kiwi species.

Night time counts of calls show that great spotted kiwis are most numerous in wet, seemingly inhospitable vegetation, 800 to 1000 metres above sea level. This suggests that the birds are upland specialists, adapted to life in a harsh and rugged landscape. But this is only partly true. The species as a whole seems to comprise an upland and lowland race, which differ from each other in body size. The larger upland race predominates today, only because introduced predators have destroyed most of the lowland birds.

Great spotted kiwis seem to have a reasonably certain future, even if they are now not as widespread and numerous as they used to be. Few predators can tolerate wet, sub-alpine conditions, so the upland kiwis should remain unharmed. The question now being addressed is whether the lowland race should be recognised as a separate taxonomic entity and preserved for its own sake. This will be resolved when investigations into the genetic make-up of great spotted kiwi are completed.

Kaka

The kaka is a forest parrot endemic to New Zealand, whose numbers have declined this century. The energetics and breeding success of a remnant population of the South Island subspecies, in a beech forest modified by introduced browsing mammals, were measured. In seven years only one successful kaka nest was found. In summer, kaka obtain most of their daily energy requirements from honeydew excreted by a native scale insect, but in autumn this food source is depleted by high numbers of introduced wasps. To test whether declining kaka numbers are due to a shortage in high energy food, a supplementary feeding experiment is being carried out. Over 20 kaka have been trained to eat solid foods and drink honeywater (replacing honeydew) daily at a feeding station. This research has shown that the supplementary food is additional to their usual diet.

The other high energy food periodically available to kaka is beech seed. High seed years contribute to higher than normal stoat populations. The only female kaka to breed successfully in the study was subsequently killed by a stoat while nesting. Fledglings which are initially flightless are also vulnerable to stoats and rats, known predators of kaka nestlings. Therefore, beech seed production and its effect on rodent and stoat numbers is being monitored to determine the relative importance of these factors in the population dynamics of kaka. Development of specialised techniques for capture, handling, radio telemetry and automatic feeding have been essential for the success of the study.

Native invertebrates

Land snails

Collectors have been attracted to New Zealand's carnivorous land snails by their large size and the variety of colour patterns. The family Rhytididae, which includes the familiar genera *Powelliphanta* and *Paraphanta*, also contains several genera of mostly smaller carnivores with plain shells. What these snails lack in visual appeal they make up for in evolutionary and behavioral interest. The richness of New Zealand's surviving Rhytitid fauna provides a special opportunity for comparative studies of feeding. Prey capture has been observed in captive snails in the genera *Wainuia* and *Rhytida* and correlated with the diet of wild snails. Carnivorous species eat other snails and worms and one New Zealand species is particularly fond of the small jumping crustaceans called landhoppers. Specialised teeth and behaviour adapt species to different diets. Some behaviour patterns found in New Zealand snails have also been recognised in their relatives from South Africa and Australia, suggesting that they may be ancient. Other adaptations appear, at present, to be unique to New Zealand snails.

Skinks and weevils

The progress and viability of small populations of skinks and weevils is being studied on several islands in Fiordland where rats have recently been eliminated. The rare Fiordland skink was re-introduced to Hawea Island following successful eradication of rats in 1986 and regular monitoring

Kaka receiving supplementary food from artificial fuchsia flowers at a feeding station.

is being undertaken to establish the rate of increase and spread of the animals in a predator-free environment. Fiordland knobbled weevils and flax weevils, released on Breaksea Island in 1991 about three years after rats were eradicated from the island, are also being monitored.

Wetas

Little is known about the distribution and status of many of the more than 70 species of weta in New Zealand. Giant wetas are New Zealand's largest and most ancient invertebrates. All species of giant wetas (*Deinacrida* species), apart from one, are regarded as rare or endangered. In 1992 a major survey was conducted in the Seaward and Inner Kaikoura Ranges resulting in the discovery of an important mainland refuge for three giant weta species. In 1976, 43 giant wetas from Mana Island were released on Maud Island where there are no rodent predators. A recent population census of this island showed that the *Deinacrida rugosa* population was well established. Biological observations, breeding techniques and requirements of giant wetas are continuing to be studied in outside enclosures in Wellington. Like many of the other large flightless ground-dwelling insects in New Zealand, tusked wetas have been eliminated from the mainland and islands where rats have invaded. Recently an undescribed species of tusked weta was found on a predator-free island in northern New Zealand.

Forgotten Fauna - *Mike Meads*

As a consequence of New Zealand's isolation from other lands and lack of native mammals, our fauna contains many primitive and giant insects which are unique. However, many of these small animals are seriously threatened by introduced predators and loss of habitat and many now survive only on islands and nature reserves.

Forgotten Fauna, published in 1990 by DSIR Publishing, describes these rare, endangered and protected invertebrates. Some of which are of considerable international scientific and conservation interest. Interesting and informative facts, including the latest research findings, are presented along with superb full colour illustrations. Separate sections examine wetas, beetles, snails and slugs, parasites, and invertebrates species threatened by natural phenomena. The book has been very popular with schools and is a positive step towards dispelling negative images of invertebrates and for fostering public acceptance and understanding of the need to conserve our native fauna.

ECOSYSTEM PROCESSES AND ENVIRONMENTAL CHANGE

This programme focuses on environmental change in relation to dynamic processes, particularly in those vulnerable ecosystems which have a range of weed, pest and other management problems. New Zealand has a biota and landscape now substantially different from that of pre-settlement times, and it is no longer feasible to separate out those aspects which are natural from those resulting from the activities of humans. Our long-term aim is to gain an understanding of the complex interactions of natural and human-induced change.

Current work focuses on four critical influences presently operating in the New Zealand environment: direct human modification of the landscape and environment, weed invasion, herbivory and predation by introduced mammals, and climate change.

Climate change and vegetation history

Studying past vegetation in relation to climate change is one way of determining how sensitive the natural vegetation is to major climatic alterations. We have undertaken analyses of fossil pollen, the distribution and age of wetlands, and soil charcoal in order to discover, in broad outline, the patterns of both climatic and vegetation change. Pollen results suggest that the early part of the Holocene (10 000 to 7000 years ago) - known from deep sea core analyses and glacial evidence to have been the warmest period of the last 100 000 years - was also the most equable, drought and frost free period. Wetlands were more restricted in distribution at this time, some lakes were dry and many peat bogs grew slowly during the early Holocene, particularly in the east. Although there were fires - as evidenced by soil charcoal - they seem not to have been as common as in the latest Holocene. We believe, on the basis of these preliminary results, that the seasonality of the climate was markedly different from the present during the early Holocene. Winters appear to have been both drier and milder than at present, while summers were both moister and cloudier. The El Niño oscillation may not have been operating as vigorously during this period. If New Zealand warms substantially over the next few decades we would expect, on the basis of these results, warmer winters and moister summers. However, the El Niño is likely to continue to have a strong effect, so episodes of prolonged drought are likely to remain a feature of the climatic regime.

Introduced animals

Introduced predators are perhaps the single most critical factor causing the decline of native birds. Concern is often expressed that when mice are common in beech forest, stoats multiply and may prey more heavily on native birds. Long-term measurements (now 21 years) of fluctuations in the mouse populations and of beech seedfall in the Orongorongo Valley have confirmed that mice numbers peak only in years of heavy seeding. Analysis of the diet of mice showed that invertebrates, especially caterpillars, spiders and beetles, are important foods. A study of insects emerging from the litter in summer revealed that moths are abundant only in years of heavy beech seeding. This suggests that the system is more complex than a simple beech seed-mouse-stoat-bird sequence and that invertebrates are an important component. Birds, as well as mice, may increase when invertebrates are abundant and predation on invertebrates by high numbers of mice might adversely affect the food supply for birds. Detailed study of these interrelationships in beech forest in the Orongorongo Valley is now in progress.

Wetlands

Wetlands play a crucial role in the health of the land. They store, release and maintain water and nutrients to the many ecosystems dependent upon them. Yet these same wetlands have been treated with scant regard for these values. They have been drained, reclaimed, and converted into farmland, often with disastrous results for the surrounding landscape. The main aim of these studies is to understand how wetlands function in the landscape so they can be managed and maintained to preserve their value.

There are many different kinds of wetlands, all of which behave differently. Some, such as estuaries and pakihi swamps, are relatively well understood. This programme focuses on those that are less well known and consequently often the most poorly managed. Coastal lagoons are crucial for wildlife and for marginal wetland vegetation. Studies of the vegetation of the margin of Lake Ellesmere (Canterbury) and the role of water quantity and quality were described. This data will contribute to management regimes for the lake which will benefit both users and the wildlife. Future studies will focus on how the many small lakes in hill country regulate the flow of water and nutrients to arable land downstream.

Woody weeds

Woody invasive weeds are serious problems in some areas of the country and are a potential problem of great magnitude nearly everywhere, in particular if there is significant climatic change. Research has focused on a few species which pose management problems, but a long-term predictive model concerning the general problem of woody weed invasion will be developed. Work has continued on *Hakea* in the Golden Bay region, Nelson Province. *H. sericea* tolerates poor soils and is spreading into low pakahi-like vegetation following fires. In mixed stands with manuka and kanuka,

these natives dominate after the *Hakea* canopy collapses. However, pure stands of *Hakea* have dense crowns which prevent native species from establishing. Once the stand begins to collapse, bracken is usually the first vegetation to regenerate.

Conifer invasion is a considerable concern in the open tussockland country of the South Island. In many areas of the South Island, conifers such as *Pinus contorta*, *Pinus nigra*, *Larix decidua*, and *Pseudotsuga menziesii* are poised to undergo secondary spread after initial dispersal from the widespread forest shelterbelts and plantations established after the Second World War. Studies of *Pinus contorta* have shown that pine seedlings can establish in snow tussock 30 km downwind from the parent plant. As these young plants can seed from about 15 years of age onwards, the potential for explosive secondary spread now clearly exists.

Forest regeneration

In recent years there has been increased interest in regeneration processes in forest and various models have been proposed for the natural replacement of the forest canopy. One specialised regeneration model, where the forest continually regenerates along a moving front of dying trees, has been reported from fir forest growing near the tree line in the Northern Hemisphere. There, a strip of dying trees slowly shifts downwind as trees exposed to the wind gradually die and fir seedlings establish under the strip of dying trees. The mechanisms driving the "wave regeneration" are frequent strong winds and cold winter temperatures causing build up of rime ice on the exposed foliage of the trees. The twigs become brittle and break off and as the trees gradually lose foliage, their vigour declines and they eventually die.

Wave regeneration was found in low altitude silver beech forest in the Rimutaka Range near Wellington, where the winter temperatures are mild, and the deposition of rime ice cannot cause the forest dieback. The sites are on ridges exposed to the prevailing northwest wind and the trees have smooth, wind-shorn and flattened canopies. The dieback zone has shifted downwind at a rate of about half a metre per year for at least 170 years. As the rate has been relatively constant the dieback cannot result from windthrow, especially as most dead trunks remain standing. Although the sites are 28 km from the sea, initial findings link the dieback to the atmospheric sea salt that deforms sensitive trees elsewhere in the region.

Soil-plant interactions in native forests

The root system is a vital link in the cycling of nutrients in the forest ecosystem. However, the role of podocarp root nodules in this process is poorly understood. Podocarps often pioneer onto alluvial soils, but many can also tolerate skeletal soils or those with impaired drainage. Root nodules are likely to be an important factor in this very wide site tolerance exhibited by podocarp trees and shrubs. The functioning of the nodules may therefore be critical to the plant's ability to withstand environmental stress. Research investigating the ultrastructure and function of the root nodules was started by the electron microscope unit at Lincoln.

Research in Orongorongo Valley

The research station in the Orongorongo Valley in the southern Rimutaka Range, established by the Department of Internal Affairs for research on possums in 1946, has been maintained and operated by DSIR since 1965. It provides facilities for research on forest ecology and on the impact of introduced animals on the forest and its inhabitants. Long-term measurements of plant and animal populations, some now exceeding 20 years, have been carried out there. They include measurements of changes in forest composition, seedfall, and the populations of possums, rodents, rabbits, predators, birds and invertebrates. This research documents the frequency and magnitude of population changes and helps to reveal the causes and complexity of these changes. Research activity in the Orongorongo Valley has recently increased and has been extended into the higher altitude forest.

DSIR Land Resources staff, as part of an informal public relations and educational programme, have talked to numerous school groups and members of the public on the work of the research station and the importance of the environment. Footage for an item on possum control was shot in the Orongorongo Valley research area by the Australian television programme "60 Minutes".

Sphagnum harvesting

About 1000 dry tonnes of sphagnum moss are exported annually from New Zealand. DSIR Land Resources became involved in studies on the sustainability of sphagnum harvesting, in response to the concerns of the Department of Conservation. This has provided an opportunity to view different sphagnum communities, study some of the ecological processes, and assess growth rates.

Growth rates were monitored at a number of sites in Westland and found to be significantly greater in lowland compared with montane sites. Although some montane sphagnum communities should not be commercially harvested, sphagnum moss harvesting is ecologically sustainable in many cases. Sustainability requires careful site treatment and reseeding of harvested areas with portions of actively growing moss, as a means of speeding recovery. The growth rate of reseeded moss is similar to that of intact moss. Shade and/or shelter significantly improves moss growth compared with open sites, principally by limiting the effect of drought.

Red Lagoon — a kettle lake with wetland margins worthy of protection in the MacKenzie Basin.

Vegetation of New Zealand- *Peter Wardle*
New Zealand, with its isolation from other lands, and latitudes ranging from the subtropical to the subantarctic, has a unique and highly diverse vegetation. *Vegetation of New Zealand*, published in 1991 by Cambridge University Press, is the first comprehensive account of our vegetation since Cockayne's *The Vegetation of New Zealand* was published in 1928. At just over 600 pages, this new work makes a major contribution to our understanding of New Zealand's plant life by incorporating the vast amount of ecological research carried out over the past six decades through-out New Zealand.

The book begins by considering the origins and ecological features of the native flora, which consists mostly of endemic species. Also discussed are factors which shape the vegetation, such as landscape, climate, historical events, and not least, human impact. Each of the major categories of vegetation are then described, including communities of both native and naturalised plants and the vegetation of remote outlying islands of the New Zealand archipelago. Concluding chapters summarise ecophysiological aspects of the vegetation and discuss recent ecological processes such as disturbance, regeneration, invasion and succession.

Ecological Processes

ECOLOGY OF INTRODUCED ANIMALS

New Zealand's native plants and animals evolved over a long period of isolation and in the absence of terrestrial mammals. The colonisation of New Zealand by people over the last 1000 years has been accompanied by a multitude of deliberate and accidental introductions. Many of these introduced animals have had drastic impacts on native plants and animals, or now threaten agricultural production by damaging crops or spreading diseases. This programme aims to increase our knowledge and understanding of the ecology and impacts of introduced animals as well as heighten public awareness of the problems caused by these animals. The research is carried out in close consultation with, and receives partial funding from, management agencies such as the Department of Conservation, the Ministry of Agriculture and Fisheries, and the Animal Health Board. This ensures that research findings will directly improve current management strategies. Advice was provided on a wide range of environmental matters, particularly relating to the proposed introduction of myxomatosis. Specimens were identified for the Health Department, Police, and Department of Conservation.

Possums in native forests

Possums are considered New Zealand's worst introduced mammal pest because of the damage they inflict upon native forests and their role in spreading bovine tuberculosis to cattle. The natural variation in possum numbers living in a lowland forest in the Orongorongo Valley, near Wellington, has been studied since 1966. This is the only intensive long-term study of possums in New Zealand. Since 1966, possum numbers have generally remained at between six and 12 per hectare, peaking at 14 in 1990. This possum population is among the least variable mammal population studied to date. Recent analysis demonstrated that the size and direction of annual changes in density are partly controlled by density itself, i.e., the variation is density-dependent and the population is regulated about an equilibrium. The main density-dependent factors for both males and females are winter mortality and immigration.

Data from this long-term study were also used to validate and improve current methods for mark and recapture analysis of animal populations. In particular, a novel age-dependent Jolly-Seber model was developed and applied to the study of immigration and emigration. These findings are being used to improve current models of possum population dynamics to allow better prediction of the outcome of current and future possum management strategies.

Continuing research on the impacts of possums in the native forest of the Orongorongo Valley has demonstrated the importance of the flowers and fruits of native and introduced plants in their diet. Possums eat the fruits of almost all fleshy-fruited plants and may strip the entire crop of fruit from a tree in a few nights. Most fruits are eaten whole, but the flesh only is stripped from larger fruits, such as those of hinau or karaka. Eradication of possums from a 20 hectare area clearly showed that possums suppress fruit production by browsing on the leaves and flowers. In the year following possum eradication, production of hinau fruit increased fivefold and all nikau palms on the area produced fruit compared with only one in the previous five years.

The Department of Conservation and the Animal Health Board also funded a variety of projects on aspects of possum biology and impact. This included research on pheromones (body odours) as attractants; a review of information on possum dispersal; research into maturation in relation to behaviour of juvenile possums; computer models for economic possum control operations; electric fencing for possum control; monitoring the effectiveness of different possum control operations; the use of aerial and satellite images to monitor possum damage to forests; and research into chemicals to deter birds from feeding on poison baits intended for possums.

Possums in farmland

Possums thrive on farmland where they can find suitable daytime refuges in scrub, farm buildings, windbreaks and riverside trees. An earlier study near Bridge Pa, Hawke's Bay, revealed as many as 270 possums living in only 12 hectares of stream-side willows. The local Pest Board poisoned 90 percent of these animals in 1988 and regular live trapping has been used to monitor the recovery of the population. After three years the population has risen to only about a third of its previous density. As the Hawke's Bay possums are prolific breeders, their recovery is much slower than expected. Immigration from the surrounding areas was also far less than expected.

Possums are largely responsible for the spread of bovine tuberculosis to cattle. Possums infected with Tb can now be found in areas covering a quarter of the country. A computer model was developed using the movements and distribution of individual possums and the probabilities of their death and infection, to predict how these areas might grow in size. The model also reveals that Tb is likely to persist only where the possum population is crowded, i.e., each possum's range overlaps with many others. This may explain the absence of Tb in

Possums are considered New Zealand's number one introduced pest (photo: Forest Research Institute).

possums in Australia where they are much more sparsely distributed.

The rate of recovery of possum populations after control, and the spread of bovine Tb, are both critically dependent on how often possums move over long distances. Juvenile possums on farmland were fitted with radio transmitters to study their dispersal. Young animals predominate among colonists after control operations and are the most frequent and longest movers. Although 80 percent of long distance dispersers are males, the longest recorded movements (up to 40 km) have been made by females. Surprisingly, even after the density of possums at Bridge Pa had been reduced by 90 percent, leaving an excess of suitable nest sites and food, some of the young animals born to the surviving females there still dispersed away from the area.

Wasps

The ecology and control of introduced wasps was studied, principally in the honeydew beech forests of the northern South Island. Honeydew is a pure sugar which hangs as silver droplets over the trunks and branches of some beech trees. Wasps reach higher densities in this habitat than in the rest of New Zealand and remove almost all the sugary honeydew for several months of the year. This means an important food source is unavailable for native birds, reptiles and invertebrates. DSIR Land Resources initiated a large-scale field experiment to remove wasps from two study areas so that the impact of wasps on the beech forest ecosystem could be measured. As well as competing for honeydew, wasps are predators of many native invertebrates, particularly caterpillars, spiders and flies. Some of this research is being funded by the Department of Conservation who will use the results to determine the level of wasp control necessary to protect conservation values.

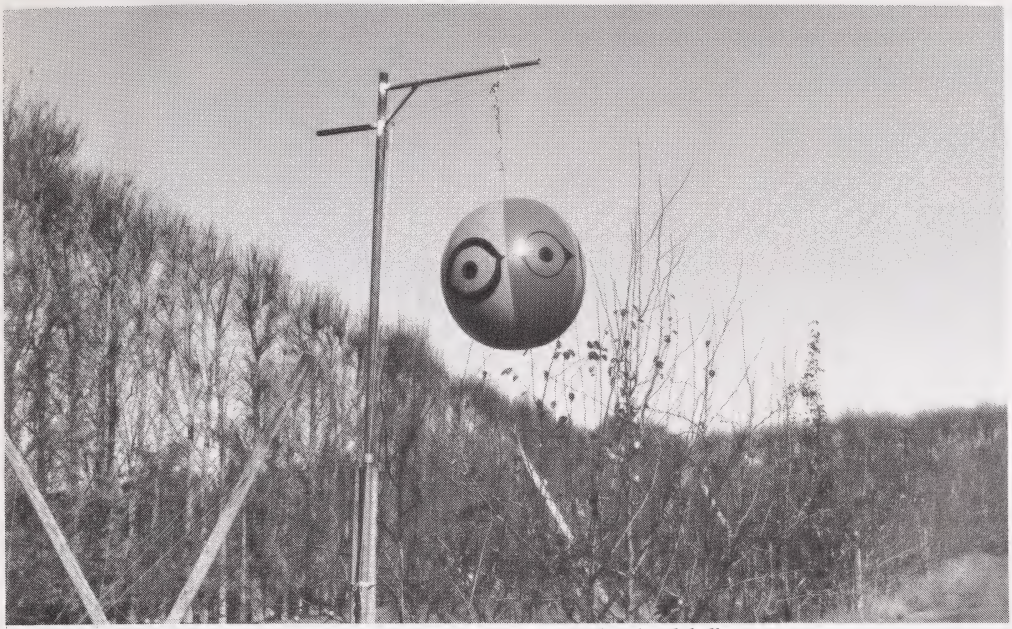
The common wasp has continued to expand its range throughout New Zealand. On the West Coast of the South Island it spread at a rate of at least 30 km per year, completely displacing the German wasp in honeydew beech forest within about three years. However, in rural and urban habitats the two species still coexist. Common wasps will continue spreading until they are found virtually throughout New Zealand.

The abundance of wasps can vary enormously from year to year as well as from site to site. Standard measurements of wasp density, queen production and the contents of wasp colonies are made at six sites every year. A preliminary model of the population dynamics of wasps was developed in collaboration with MAFTech and Otago University. This model evaluates the annual fluctuations in wasp numbers and predicts when wasps are most vulnerable to control measures. Data from at least another three years research are needed to confirm the predictions of the model.

Wasp nests are also inspected for the presence of the parasitoid, *Sphecophaga vesparum*, which was released in New Zealand in 1987 by DSIR Plant Protection. The parasitoid has established at Pelorus Bridge, near Nelson, but has not been recorded at other release sites. At Pelorus Bridge the parasitoid has dispersed at least 2-3 km per year, but the proportion of nests parasitised has remained at about five percent. Data from this research are also being incorporated into a mathematical model so that the effectiveness of the parasitoid in reducing wasp populations can be predicted.

Mammals on islands

The study of mammals on islands allows examination of the influences of different levels of human interference and the effects of various combinations of introductions. A world-wide database of islands with rabbits was compiled and is currently being used to examine the complex effects of habitat, predators and myxomatosis on rabbit populations. A database of introduced mammals on all New Zealand islands greater than five hectares was completed and is being used by



Bird damage can be reduced in vineyards when large eyes are painted on beach balls.

the Department of Conservation to assist with assignment of priorities for animal control.

Management of introduced animals needs to be justified in terms of the benefits to the conservation values at risk, so it is important that the impacts of such animals on native plants and animals are well known. Seabird colonies on Raoul and Chatham Islands were thought to be threatened by feral cats. But studies of the cats' diet has revealed that on both islands they eat mostly rats plus some land birds and only a very few seabirds. On Raoul Island, cats ate mostly kiore (the Polynesian rat) and ignored the larger, more aggressive Norway rats. Since Norway rats also prey on seabirds, eradicating the cats without also controlling the rats would be unlikely to result in much improvement in the bird populations. Experimental reduction of cat numbers in the Orongorongo Valley was followed by a substantial increase in rat numbers, which may have threatened forest birds more severely than the original cats because they climb trees. These studies of the interactions between feral cats and their prey indicate that in some circumstances the best cat is not necessarily a dead cat.

In recent years introduced mammals have been eradicated from an increasing number of New Zealand islands by the Department of Conservation. Rats and rabbits were removed from two islands in the Mercury group, and possums from Kapiti Island. DSIR Land Resources staff have helped to measure the benefits of such management by studying the recovery of the vegetation. In each case, there has been a spectacular flush of new growth. How the vegetation on these islands changes with time remains to be discovered, but already some initial hypotheses about the paths of successional change have had to be revised.

Bird pests

Birds often cause significant losses in vineyards, estimated at over $1 million each year in the Hawke's Bay district alone. Until recently, most grape growers sprayed their crops with Mesurol to repel birds, but this chemical has now been banned for use on export wines because of unacceptable levels of residues.

In 1991, DSIR Land Resources began searching for an environmentally friendly successor to Mesurol, concentrating mainly on natural compounds that plants make to protect their leaves or fruit from being eaten by animals. Initial tests with tannin gave promising results. Captive house sparrows generally switched to less preferred foods when their favoured food was treated with a weak solution of the chemical. However, recent field tests suggest that tannin does not have a commercial application. It does protect grapes from birds - but only at high concentrations which are uneconomic to apply. Chemicals which might be added to tannin to increase its effectiveness are now being investigated, along with others which might act as stand-alone repellents.

While the search for a suitable repellent continues,

growers must use other methods of protecting their crops from birds. Field trials show that multi-coloured beach balls, with large eye-spots painted around the middle, are surprisingly effective at discouraging birds from entering crops. The eyespot balls apply the super-stimulus principle, used, for example, by some insects who flash elaborate eye spots on their wings to startle approaching predators. Few birds land within 20 metres of the eyespot balls, although their effectiveness wanes with time and generally disappears altogether after about two weeks. Methods of enhancing both the effective life of the balls, and the impact of their eyespots, are currently being tested with encouraging results.

Giardia in wild animals

Giardia intestinalis is a water-borne protozoan parasite which causes gastric problems in humans and is of increasing concern to local authorities responsible for water quality. Although the parasite is usually spread by faecal contamination, wild animals may also provide a source of infection; for example, beavers in North America are capable of passing the infection to humans by contaminating water supplies. DSIR Land Resources is participating with Massey University in a study of the distribution of *Giardia*, particularly the maintenance of a persistent *Giardia* infection in the Dannevirke area. The research aims to define the role of wild animals as vectors of *Giardia* and their importance in the spread of the disease to humans and into the environment. This information may help with the development of appropriate strategies for managing *Giardia* infections in public water supplies and people. Through survey trapping and faecal sampling it was found that *Giardia* infects a wide range of wild animals throughout the North Island of New Zealand. *Giardia* cysts have been found in possums, rats, mice, hedgehogs, rabbits, blackbirds, thrushes, chaffinches and magpies. Research is now needed to establish whether the *Giardia* found in these wild animals is capable of infecting humans.

DSIR Land Resources is collaborating with Hutt Hospital to explore the history and epidemiology of *Giardia* infection in wild populations of possums and rodents. Information collected over the last 20 years in Rimutaka Forest Park, an area of native forest with high recreational use in the Orongorongo Valley, is being used to evaluate the relative importance of rodents and possums in contaminating water supplies. Recent samples show that about 60 percent of the rats and 15 percent of possums have cysts of *Giardia intestinalis*. However, samples from the 1970s show that less than five percent of rats were infected then. This dramatic increase may be related to higher rat numbers which developed after the eradication of feral cats in 1986. Further samples are being analysed to pinpoint the timing of the increase in the prevalence of *Giardia*.

The annual census of Adelie penguins in the Ross Sea region, Antarctica.

ADELIE PENGUINS IN ANTARCTICA

The breeding locations and numbers of Adelie penguins in the Ross Sea region have been determined by aerial reconnaissance and photography since 1981. This research is part of the International Survey of Antarctic Seabirds undertaken by various nations in different sectors of Antarctica. Adelie penguins, in New Zealand's sector in the Ross Sea, breed over a latitudinal range of 1200 km from the Balleny Islands to Ross Island. Significant changes in penguin numbers could warn of changes in the abundance of their major prey, krill, and in the health of the Antarctic marine ecosystem. The ecosystem faces threats from continued whaling, over-fishing, krill harvesting, oil spills and other human-induced changes.

Adelies breed on ice-free, stony areas, and return to the same rookery site each year. They are photographed from the air in early December when most birds ashore are incubating eggs while their mates and most non-breeding birds are feeding at sea. The number of penguins incubating eggs are counted under a magnifying lens from enlarged photographs. Every December, the number of birds

in the Cape Royds rookery is counted on the ground to calibrate these aerial photographs. Chicks are counted, weighed and measured at Cape Crozier and Cape Royds in January to compare growth rates and establish a condition index for comparison between these two chick populations.

The overall estimate of the number of breeding pairs has increased from 616 500 to over 1 000 000. This is mainly a result of the greater accuracy of aerial counts and a real population increase since 1981, rather than the recent discovery of 11 previously unknown breeding sites with a total population of 63 000 breeding pairs. To determine the likely causes of the increase in breeding Adelies, a computer model of the population dynamics of the Cape Royds rookery was developed. Although variations in the extent of sea ice around a rookery during incubation and chick rearing can affect productivity, it cannot explain the population increase measured. Likewise, depletion of competing baleen whales is not a factor, because of the timing of the population increase. Recent warming of the Ross Sea climate is the most probable cause, which suggests the dynamics of Adelie penguin populations may be very sensitive indicators of changes in the Antarctic climate.

SOIL MANAGEMENT FOR SUSTAINABLE CROP PRODUCTION

The goal of this programme is to develop sustainable crop management practices which protect soil resources from degradation. Research is aimed at gaining a better understanding of soil structure-tillage interactions in order to develop and promote preventative or ameliorative soil management practices. The programme also seeks to enhance understanding of nutrient and element dynamics in soils. It is this interaction which determines the availability of water and nutrients for plant uptake and the potential for leaching to ground water with consequent environmental implications.

Sustainable cropping

Soil compaction

Soil compaction, where soil particles are rearranged and forced closer together, is a major farming problem in many parts of New Zealand. It is caused by intensive and untimely cultivation, animal trampling, and the use of heavy agricultural machinery. Soil compaction destroys the structure of the soil material thereby reducing aeration and drainage and increasing penetration resistance which restricts root growth. Soil compaction also limits nutrient availability. Research into the behaviour of important cropping soils in the Manawatu has shown that soil degradation under untimely or intensive cultivation can make grain cropping unsustainable and uneconomic within eight to ten years. Productivity losses caused by soil compaction cannot necessarily be overcome by improved agronomic inputs such as fertilisers or new cultivars. Areas of arable land susceptible to soil degradation need land management guidelines to ensure their long-term economic and ecological sustainability.

Preventative management practices to protect the soil from compaction were investigated. These involved scheduling tillage and machinery operations to avoid wet conditions whenever possible. Crop rotation practices, designed to return organic matter to the soil, were also investigated. Research is being undertaken to determine the recovery rates of physical and biochemical properties and soil fertility under ryegrass/clover pastures. In collaboration with Massey University, field trials were set up to determine the effectiveness of conservation tillage and subsoiling techniques in countering or preventing soil structure deterioration. Conservation tillage methods prepare the ground for planting in a manner which is less damaging to the soil structure than conventional methods. Subsoiling practices, which mechanically shatter the soil to depths below the normal tillage zone, are being trialed. Ultimately this research will

Effective irrigation design and water allocation procedures increase profitability and are more environmentally sustainable.

Heavy earthmoving machinery can cause severe soil compaction.

provide crop growers with management strategies and cultivation techniques to reduce soil compaction problems.

Rate of soil erosion

The first study to quantify the rate of surface erosion by wind and water of New Zealand soils under intensive cultivation was undertaken. Two different approaches were used, the first involved an analysis of the abundance of radioactive caesium-137 in topsoils of the South Canterbury downlands and the Manawatu. Atmospheric fallout from nuclear testing during the 1950s and 60s has resulted in a characteristic labelling of topsoils with caesium-137. Once it reaches the ground, caesium-137 is tightly bound to soil particles and is only moved by the process of erosion and deposition. Measurement of variation in the amount of caesium-137 between individual paddocks and comparison with the original input from fallout provides an index of the rate of soil erosion. The technique provides an estimate of the amount of erosion that has occurred since fallout began in the early 1950s.

The second approach to measuring the rate of erosion is being used in the Pukekohe market garden area. In this area, high intensity storms periodically produce runoff and sediment discharge into small streams. An automatic stream gauging and sediment sampling site was established on one of these streams. By measuring the stream flow and concentration of sediment in the flow an estimate of the total quantity of sediment transported from the representative catchment can be determined. The erosion rate can be calculated once the total quantity of sediment and the area of the catchment are known.

Soil acidity and aluminium toxicity

Soils which are strongly acidic, i.e., with a pH less than 5.0, often contain high levels of labile aluminium. This aluminium restricts plant root growth, reduces yield and increases sensitivity to environmental stress such as drought. To determine the extent and distribution of toxic aluminium in soils in New Zealand, each parcel of land was identified by soil type and classified by a level of acidity. Using a Geographic Information System, information from various databases, in particular, the New Zealand Land Resource Inventory, was integrated and a pH map of soils generated. The results show that large areas of New Zealand have acid soils that are potentially toxic for plants because of excessive labile aluminium levels.

Overseas research shows that it is possible to modify soil acidity by adding gypsum. Preliminary laboratory experiments were carried out to assess the effects gypsum on soil pH and the level of toxic forms of aluminium in acidic soils. Results of a field test showed that the extremely high and toxic levels of aluminium in Mapua soils, used for apple production near Nelson, were halved when gypsum was added to the soil.

Sustainable soil fertility

Some soil biochemical properties have been shown to be sensitive indicators of soil fertility and soil degradation. The numbers and activity of soil organisms can be inferred from the concentration of end or by-products of microbially mediated processes such as nitrogen or sulphur mineralisation. The development and appraisal of new techniques to measure microbial activity in soil is an important part of soil biochemical research. The increased understanding of soil processes that these techniques afford expands our capacity to understand and predict the consequences of different land management practices. Often, early warning of soil degradation can be given by these techniques before it becomes a serious problem. A novel technique for measuring soil microbial activity, based on the reduction of dimethyl sulphoxide (DMSO) to dimethyl sulphide (DMS) by soil microbes, has been developed and assessed in several different soils and under different forms of land management.

Soil nutrient losses under kiwifruit vines

Most kiwifruit growers apply some fertiliser to their vines, but we do not know how much of this fertiliser contributes to plant growth and how much is lost from the soil. Nutrients, such as nitrogen, potassium and sulphate are transported through the soil profile with rainfall and may be leached out. The rate of this movement depends on the type of soil and how strongly different nutrients bind to the soil. DSIR Land Resources, in collaboration with DSIR Fruit and Trees, investigated the nutrient losses from a Te Puke sandy loam soil under kiwifruit production. Analysis of soil samples taken at different depths and times allowed the movement of nutrients through the soil to be tracked and nutrient losses to be estimated.

The results show Te Puke soils lose significant amounts of nutrients. Most of this nutrient loss occurs in winter when large amounts are leached through the soil profile and when the kiwifruit vines are not absorbing nutrients. About 40 percent of both potassium and sulphate and 45 percent of nitrogen contained in fertiliser are lost. Further research is continuing to confirm estimates of nutrient recovery from fertilisers by kiwifruit vines. This work will be essential for predicting fertiliser requirements and understanding processes leading to the pollution of groundwater.

Water in soil

The way soil accepts, stores and transmits water is the result of an interaction of important processes in nature. Infiltration, the way water enters the soil system, is dependent on surface conditions which can be severely affected by land management. For example, when conditions are wet, compaction from treading or vehicle movement can reduce infiltration by reducing pore space.

Once water enters the soil, its movement through the soil is controlled by the permeability of soil layers and the presence or absence of interconnecting pores or cracks. Moisture storage, which is important for plant growth, occurs when moisture movement by gravity through the larger pores slows to insignificant rates and capillary attraction becomes the dominant force.

Continuing from the Soil Water Assessment and Measurement Programme (SWAMP) of the 1980s, when a field methodology was established for measuring and assessing soil water movement, recent work has concentrated on using these data to model water movement into and through soil profiles. A better understanding of the way water behaves in soil means that, among other things, methods can be developed to improve irrigation efficiencies. This can lead to reduced costs for the grower and reduce the percolation of water, nutrients and pesticides to groundwater.

Allocation of water rights

Research toward the development of a scientific rationale for allocating water rights for irrigation was undertaken. The present system of water right allocation is based on an assumed non-specific crop-water need. The ability of the particular site to handle water, i.e., its soil hydraulic properties, does not feature in the allocation process. Nor does the specific water requirement of the actual crop, or the type of irrigation system used. Water allocation procedures that take account of site, crop and management factors should result in greater efficiencies, better root-zone management and reduced deep percolation. The latter is particularly important environmentally, as the contamination of aquifers through poorly managed irrigation is a significant risk.

Data sets of soil physical properties were assembled for key soils in the Blenheim (Marlborough), Lincoln (Canterbury) and Hastings (Hawke's Bay) areas. Using these data, computer modelling will facilitate studies of the response of the soil system to simulated irrigation regimes. Results from the modelling studies will be compared with on-site field experience. Better matching of irrigation technique with crop and site characteristics should ensure environmentally sound management, and a more robust and defensible water allocation procedure for regional councils.

Sustainable forestry

Soil compaction

Heavy machinery used for log harvesting and site preparation causes soil compaction in forests. This compaction can reduce productivity by creating soil properties undesirable for plant growth, for example, poor aeration which restricts root growth. Compaction may also increase runoff which leads

to erosion and nutrient loss. Compaction as well as retarding tree growth can increase the likelihood of windthrow.

Field and laboratory trials were established jointly with Forest Research Institute to determine the level of compaction caused by tree harvesting in production *Pinus radiata* forests at Tarawera and Kinleith in the central North Island. Techniques for ameliorating compaction, such as deep ripping, were also evaluated. Results show changes to some soil physical properties, in particular decreases in soil conductivity of water, and that compaction also affects seedling growth.

Soil fertility

Some plantation forests require additions of the plant nutrient nitrogen, while others require phosphate for sustainable production. Usually most of the nitrogen and phosphate is stored in the soil. As nitrogen is lost during the harvest of trees, the next crop of trees may have an inadequate nitrogen supply. Various management schemes for harvesting, including harvesting whole trees, harvesting stems only, and clearing the forest floor, were used in trials set up by Forest Research Institute at Woodhill forest in Northland.

Nitrogen levels were measured in the litter and soil fractions as well as in the trees to determine the effect of harvest management regimes on the availability of nitrogen to trees. Significant changes in nitrogen levels of various soil pools, such as the more readily available microbial pool, were found.

Some Northland forests grow on soils which are deficient in phosphate. Phosphate is released from the organic matter in these soils, although the amount released is unknown. New methods are being developed, in collaboration with FRI, to measure the amount of phosphate released. Marked differences in soil animal populations were found between the treatments in the trials both with nitrogen and phosphate. These differences reflect the nutrient status of the forests and influence the rate of movement of the nutrients through various pools.

ASSESSMENT OF POLLUTION ON LAND

New Zealand's land-based economy relies heavily on chemical inputs (e.g., inorganic and organic fertilisers) to maintain or enhance production and product quality. Land-based systems are also being increasingly examined as a means of disposal of human, farm and industrial effluent and waste. These additions to the soil/plant system have the potential to pollute and contaminate soils, surface and groundwater, and ultimately, may pose a threat to animal and human health. This programme focuses on the adverse effects of these additions and involves research aimed at understanding, predicting, and where possible, controlling such impacts.

Pesticides in soil

1080

1080 poison is widely used to control introduced pests such as possums in native forests and rabbits in Central Otago. However, 1080 is a non-specific toxin which kills various litter-dwelling invertebrates, mainly insects. To assess the effect of this pesticide on such non-target organisms, the amount and kinds of litter-dwelling invertebrates were determined using pitfall traps. By checking the contents of traps at regular intervals it was possible to construct a profile of the invertebrate population, i.e., how many and which species are present on the forest floor and how this changes seasonally. Areas of forest, both immediately prior to and after 1080 cereal baits were dropped by helicopter, were surveyed for 12 months. A comparison of the resulting profiles showed that some invertebrate species were more noticeably affected than others by the poison.

Determining how long invertebrates will be exposed to the poison depends on the rate at which 1080 is broken down by microbes and/or removed from the litter zone by leaching during rainfall. These mechanisms of 1080 loss from baits are being investigated. Preliminary results show that 1080 decomposes slowly at 10°C and that it is readily leached through soil.

DDT

DDT was used extensively in the 1950s and 60s to control grass grub and porina caterpillar, both of which adversely affect pasture production. Because of its low water solubility, DDT persists in the topsoil and is taken up by grazing animals who ingest contaminated soil. DDT residues are fat soluble and therefore concentrate in the body and milk fat of sheep and cattle, prejudicing the acceptance of New Zealand meat and butter in overseas markets. Although more than 20 years have lapsed since DDT use was banned, residues are still being detected in New Zealand meat at levels close to, and above the limits set by overseas authorities.

DDT is chemically stable and persists in the soil and interacts with soil constituents. Investigations of soil-surface characteristics were carried out to determine the nature of this interaction. Methods to enhance the breakdown of DDT residues in the soil are also being studied. Experiments to speed up microbial decay of DDT in soil by sieving, applying a surfactant and adding an organic amendment were carried out. Early results show that the organic amendment treatment leads to accelerated DDT breakdown. The potential for the chemical detoxification of DDT in soil was assessed. The addition of potassium polyethylene glycolate (KPEG) significantly reduced the level of DDT in contaminated soil while raising the levels of DDE, the principal breakdown product of DDT. The

mechanism of this reaction is now being investigated.

Biocontrol of pathogenic fungi
Pathogenic fungi, a major cause of plant disease, are usually controlled using chemical sprays. Alternatives, such as the biocontrol of root infecting fungi using microbial control agents, are being investigated. However, a major stumbling block is the poor survival of introduced microbes which are out-competed by indigenous soil organisms. Research is being undertaken to enhance the survival of potentially useful microorganisms by growing them within protective mineral matrices. Minerals occurring naturally in the soil have a variety of different surface properties and their influence on microbial survival is being quantified.

Soil contamination

Cadmium
Conventional New Zealand agricultural practices rely on the use of phosphate-based fertilisers. Rock phosphate sources naturally contain the heavy metal cadmium. Cadmium concentrates in the kidneys of grazing animals and at high concentrations can render them unfit for human consumption. Theoretically, soils with a history of fertiliser application will have accumulated cadmium. To test this hypothesis, cadmium levels in archived soil samples collected in the 1940s, prior to aerial top-dressing, were measured. By comparing these results to analyses of recently collected soils from the same sites, it is possible to assess the rate of accumulation of cadmium in different New Zealand soils. The release or desorption of cadmium from soil under conditions similar to those in the digestive tract of grazing stock is also being investigated. Early results show that desorption does not occur under alkaline conditions - only under acid conditions.

Heavy metals
Limits for the amounts of heavy metals that can be added to soils (e.g., in sewage sludge) are based upon those proposed for EEC countries or USA. These limits are often inappropriate for New Zealand's climate, soils and land management practices. The toxicity of heavy metals to soil organisms and the effect on biochemical processes is being assessed in a range of New Zealand soils. Investigations have concentrated on the amount of metal added and the amount of metal that can be readily extracted back out of the soil. This latter property closely mimics the availability of heavy metals to plants, animals and humans.

Results to date show a wide range in the sensitivity of soil biological and biochemical properties to heavy metals as well as differences between metals. Results also indicate the more complex a soil process is, the more sensitive it is to heavy metals.

Land-based effluent disposal
Soil is an excellent medium for the disposal of wastes because it is plentiful, it is a natural filter and it contains organisms which biodegrade organic materials. The major organic waste materials are farm wastes, such as animal excreta and crop residues, sewage effluent and sludge, and certain industrial effluents such as from meat processing, timber, pulp and paper, and dairy industries.

Research is being undertaken on the sustainability of land-based effluent treatments. A change in management, such as application of effluent can drastically alter soil characteristics. The changes imposed include increased effective rainfall, changes in vegetation, and effects of chemicals, i.e., nutrients, salts and toxic compounds. These may ultimately affect the sustainability of the land treatment operation by altering the physical, chemical and biological properties of the soil to such an extent that the continued application of the effluent is not possible or reduced loadings are required. Sites receiving treated sewage effluents and dairy factory effluent are being tested for changing soil biochemical and physical properties. The results of this research will enable land-based effluent renovation systems to be designed for long-term sustainability.

Nitrate leaching in soils
Groundwater in Canterbury carries a moderate loading of nitrate-N. This form of nitrogen is toxic and upper limits of 10 parts per million in drinking water have been adopted. One possible source of this nitrate in Canterbury is the nitrogen released by the breakdown of soil organic matter when soil is ploughed in autumn. The effectiveness of nitrification inhibitors, which prevent nitrate formation in soil, are being assessed following autumn ploughing. Early results show that the inhibitor dicyamodiamide (DCD) does reduce the amount of nitrate in soil through until spring. Subsequently, other inhibitors were shown to be ineffective. As nitrification inhibitors prevent nitrogen from being leached out of the soil horizon, additional nitrogen may become available for plant growth in the following spring. This possible agronomic advantage is being assessed.

CARBON CYCLING AND CLIMATE CHANGE

Changes in land use over time, as well as increases in fossil fuel use, have resulted in the steady build up of greenhouse gases such as carbon dioxide (CO_2) and nitrous oxide (N_2O) in the atmosphere. This trend can be slowed or even reversed by changing patterns of land use and management. This programme aims to provide information for developing policy on the most appropriate strategies for managing New Zealand's terrestrial ecosystems,

Disposal of waste on land is an increasing environmental problem.

so as to counter the effects on, and of, global climate change.

Carbon cycling and climate change

Carbon is constantly transferring between the ocean, atmosphere and land in a vast global system known as the carbon cycle. The amount of carbon stored in the ocean and atmosphere is reasonably well known. However, the carbon levels in soils and vegetation are poorly known because of the complex and variable nature of these living systems. Knowing how much carbon is in terrestrial systems, and the rate at which it is taken in as organic matter and released as carbon dioxide and methane, has become a matter of some urgency. Warming is one of the consequences of global change that will alter the rate at which carbon is both taken in and given out by terrestrial systems. There is also the possibility of major rapid releases of carbon dioxide and methane from deteriorating wetlands and permanently wet or frozen soils. As a result, an international effort is now underway to document the amount and fluxes of carbon world-wide.

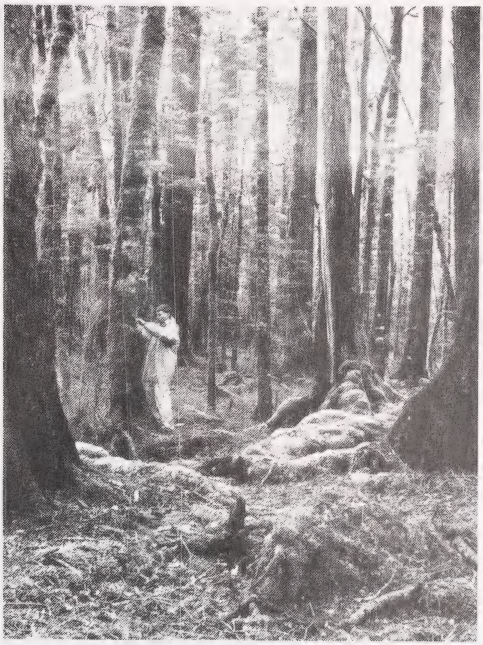
As DSIR Land Resources's contribution to international research, a New Zealand carbon map showing the level and distribution of carbon in soils and vegetation was produced. The map was constructed from data compiled and interpreted from the National Soils Database, which contains information on the level of carbon in soils dating back to the 1940s. Information on carbon levels in the major vegetation types (grasslands, forests, crop and scrub) was obtained using the New Zealand Vegetation Cover Map, and estimates of above and below ground biomass.

Related research involves the development of a model of soil organic matter turnover that can predict changes in soil carbon levels up to 200 years into the future. The ability of soil to store and release carbon is affected by land use practices. When developed, this model will be combined with the New Zealand carbon map to provide a powerful tool for determining the effect of various land management regimes on the carbon levels in the soil, and consequently, in the atmosphere.

Carbon dioxide exchange between forest and atmosphere

Large amounts of carbon are stored in litters and soils, as well as in the biomass of trees. Deforestation contributes to global warming by speeding up the release of this carbon into the atmosphere. Therefore, determining how long carbon is stored in the litter and soil before being lost as carbon dioxide is of vital importance to greenhouse studies.

A joint research programme with Forest Research Institute, DSIR Physical Sciences and DSIR Chemistry, to measure the amount of carbon dioxide



Carbon dioxide exchange is being measured in native beech forest at Maruia (photo: John Hunt, Forest Research Institute).

exchange between the atmosphere and a lowland native beech forest at Maruia, Nelson district, was undertaken. This work has led to a greater understanding of how the soil contributes to regional and global carbon cycles. For example, results of this study show that, on average, carbon remains in the soil for over 200 years before being lost as carbon dioxide.

Pastoral agriculture and greenhouse gases

Carbon dioxide

The level of atmospheric carbon dioxide is steadily rising at the rate of one part per million every year. This affects plants, and agricultural production, by influencing the rate of plant growth and the ratio of certain plant species, i.e., C_4 plants fare better than C_3 under increased carbon dioxide levels. This can lead to the establishment of new pests and weeds which affect pastoral yield and palatability to grazing animals.

As New Zealand's economy is heavily dependent on pastoral agriculture, it is essential to be able to predict these and other effects of higher atmospheric carbon dioxide concentrations on pasture. Collaborative research with DSIR Grasslands and MAFTech will, in the future, involve setting up field experiments which simulate conditions likely to develop over the next hundred years when an atmospheric carbon dioxide concentration of 500 parts per million or more will be reached. Current collaborative experiments in controlled climate rooms are in progress at Flock House. The effects on pasture (above and below ground) and soil, in particular carbon and nitrogen cycling, are being measured to develop models for testing in the future field experiments.

Nitrous oxide

Nitrous oxide (N_2O) is a greenhouse gas contributing to global warming. The main, almost exclusive, source of nitrous oxide is via the process of denitrification, in which nitrate is converted to nitrous oxide through the action of certain species of bacteria. This important biological process takes place in soils and sediments where there is some degree of oxygen depletion.

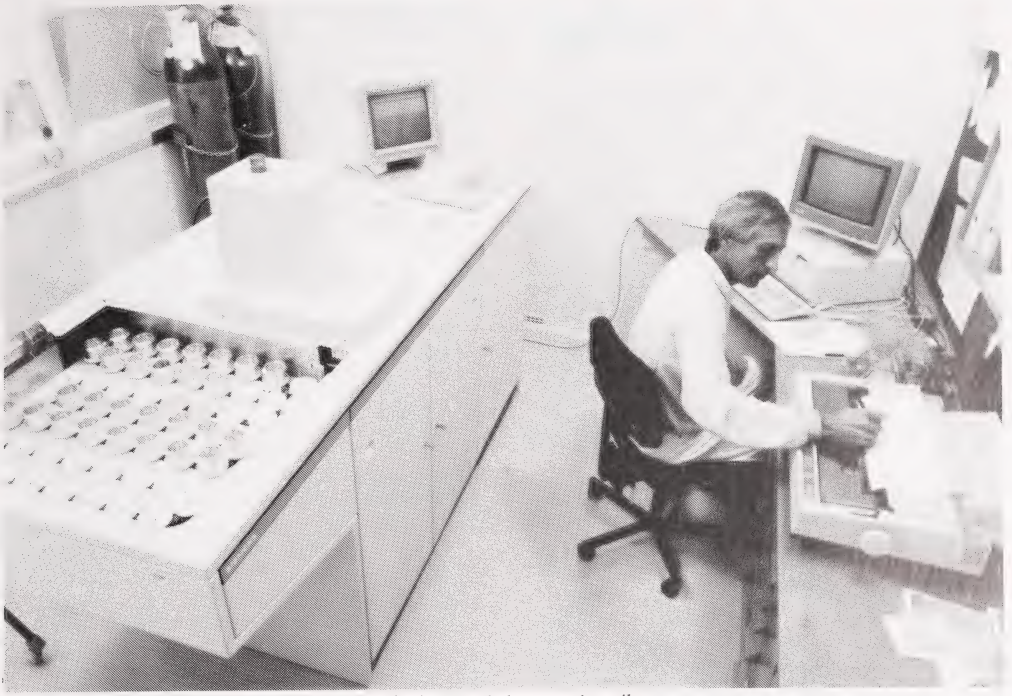
Denitrification is extremely variable in soils, which partly accounts for the lack of available quantitative data on the role of different soil types and land management practices as factors controlling the amounts of nitrous oxide produced. A very sensitive radioisotopic technique is being used to examine the factors controlling nitrous oxide production from different soils. In addition, a new and simple method for measuring nitrous oxide production by gas chromatography has been developed. These techniques are being used to determine the contribution of New Zealand's pastoral agriculture to levels of nitrous oxide in the atmosphere.

REACTIVE CONSTITUENTS OF SOILS

Most of the important chemical and physical processes in soils and sediments depend on interactions at the surfaces of very small mineral particles and organic matter. DSIR Land Resources is investigating the molecular structure of these constituents and their surface properties to improve understanding of the principles underlying research aimed at the effective management of New Zealand's soils and natural environment. Linking existing information about New Zealand's soils with new knowledge about reactive soil constituents from international and national collaboration is an important element of this work.

Soil minerals

New Zealand soils contain relatively high concentrations of poorly-crystalline minerals. These minerals have very small particle sizes and hence very high surface areas and reactivity. Siliceous ferrihydrite, a reactive iron oxide which adsorbs phosphate strongly, is believed to be an important factor influencing soil structure. X-ray diffraction studies show the structure of siliceous ferrihydrite to consist of extremely small spheres made up of many smaller units or "domains of crystallinity". Silicate is located on the surfaces of, and bridges the domains. This model demonstrates that most of the phosphate absorbed by ferrihydrite is difficult to



X-ray fluorescence spectrometer used for analysing total elements in soils.

recover as it is trapped inside the spheres. The small proportion of phosphate held on the outside of the spheres, however is released more readily.

Allophane, a characteristic mineral of soils formed in volcanic ash, has been the subject of DSIR research for many years. In collaboration with DSIR Chemistry, nuclear magnetic resonance spectroscopy was used to improve the structural model of "hydrous feldspathoid" allophane which occurs in a very pure form at Silica Springs, Mt Ruapehu. The nature of the structure indicates that this type of allophane is most likely to form in soils and sediments with relatively high pH values.

Halloysite, a crystalline clay mineral, occurs commonly in soils derived from volcanic ash. It has a phyllosilicate atomic structure consisting of repeating layers of polymerised molecules. The interlayer or "sandwich filling" spaces between the layers of phyllosilicates often determine the availability of plant nutrients, such as potassium and magnesium, and the retention of organic matter. Halloysite can exist in a variety of crystal shapes and this influences some of the physical properties of soil. In collaboration with the National Institute for Environmental Studies in Japan, X-ray photoelectron spectroscopy was used to investigate the reasons for the differing shapes of halloysite, especially the effect of iron atoms in the molecular structure.

Inert soil organic matter

All soils contain a very old organic matter component that resists microbial decay. Determining the level and properties of carbon locked in this fraction will contribute to our understanding of soil carbon turnover. This organic matter is thought to be biologically inert due to its intimate association with clay minerals. Studies in collaboration with DSIR Chemistry and DSIR Physical Sciences were carried out to isolate and date this inert organic fraction in an Otago upland soil. Results show that the clay fraction provides chemical and physical protection and in this instance the age of protected soil organic matter was exceptionally high, i.e., 6700 BP.

SOIL AND PLANT ANALYTICAL GROUP

The DSIR Land Resources analytical group is recognised internationally for the quality and range of soil and plant analytical data and for its record over many decades in method development, preparation of laboratory manuals and staff training. The analytical team provides data for a wide range of divisional research programmes and commercial clients. A large amount of chemical, mineralogical, physical and total element data on New Zealand and Pacific Island soils is stored in the national and overseas databases.

Specifically, the analytical group provides chemical analysis of soils and related materials, including soil amendments, composts, plant material, landfills and effluent, for characterisation and to identify possible limitations to plant growth. Total element analyses, using state-of-the-art X-ray fluorescence spectrometry instrumentation, are undertaken to determine naturally occurring major oxides and trace elements in soils, rocks and organic materials as well as environmentally sensitive toxic elements in waste materials. Mineralogical analysis of soils and rocks is useful for predicting soil stability and determining soil suitability for agriculture, horticulture, forestry and effluent disposal. Mineralogy also provides essential information for the ceramic and mining industries. Physical analysis provides data relating to the particle-size distribution and strength of the physical framework of the soil as well as the ability of soils to store and transmit water, solutes and air. These measurements are important for irrigation, tillage and erosion assessments.

EARTHQUAKE RESEARCH

The violence of ground shaking during an earthquake depends on the local regolith, i.e., all the geological material covering the bedrock. More flexible material shakes more violently, and this means that recent fine-grained sediments are hazardous. This was demonstrated by the great variation in damage sustained by buildings in the 1985 Mexico earthquake, where some buildings in Mexico City collapsed while others were undamaged.

The Mexico earthquake provided the impetus for continuing research on the reasons for differences in ground shaking. Techniques were developed to allow ground flexibility to be measured directly as well as showing what sizes of particle exist at depth. Measurements of earthquake vibrations on a peat-filled depression, and analysis of other research data have shown that soft material filling local depressions rhythmically oscillates to and fro as a single unit, either swirling or sloshing as the earthquake shakes it.

The major hazard is now considered to be a large distant shallow earthquake pushing deep basins full of fine grained sediment into vigorous oscillations, with the fine grained material providing cohesion which holds the ground together and prevents the shaking from being decreased by the breakup of the ground. Research is continuing to increase understanding of the details of this process. The work will continue under the umbrella of the Institute of Geological and Nuclear Sciences.

SOIL CONSERVATION AND LAND REHABILITATION

This programme is concerned primarily with assessment and control of soil erosion and the rehabilitation of land disturbed by mining or other excavations. This research aims to maintain the productive and aesthetic value of landscapes. In many areas, sustainability of a particular land use is measured largely in terms of acceptable rates of soil loss or by the impacts on soil productivity.

Erosion control in soft rock hill country

New, cost effective techniques were developed for producing measures of the performance of erosion control techniques in soft rock hill country. In contrast to other techniques which rely on expensive measurements of movement or sediment discharge, the new techniques rationally interpret a large number of relevant observations which can be easily made on site. Because erosion rates and slope stability can be difficult to assess accurately, the techniques makes use of probability theory to produce conclusions with a specified level of confidence. Separate procedures were developed for gully, earthflow, and landslip erosion - the three major erosion forms affecting soft rock hill country. The procedures have been computerised to allow interpretation of field data, report generation and updating of a database of erosion control case studies.

The techniques were applied in a major survey of the performance of gully and earthflow erosion control on farms in the Gisborne-East Cape region. Analysis of the database of 280 case studies has provided the first empirical basis for recommending erosion control practices for these erosion forms. Erosion control guidelines have been formulated in terms of matches between classes of erosion treatments and problems, and also in terms of the spacing and percentage cover of tree planting. These latter recommendations are useful in feasibility studies for more sustainable, silvopastoral land uses.

Controlling erosion in pumice lands

As an initial step towards preparation of an erosion control methods manual, techniques used to control gully erosion in pumice lands are being documented. These lands, which cover about 14 percent of the North Island, are sensitive to environmental change and are likely to undergo future land use intensification, such as a change from beef to dairying or from dairying to cropping or horticulture. This intensification of land use will increase the risk of gully erosion.

Traditional erosion control techniques include drop structures, piping, damming, retirement, water diversion, sink holes and tree planting. These techniques have been developed through experimentation by two generations of soil conservators. However, little documentation of this work exists so much of this knowledge is in danger of being lost.

This project aims to document the range of techniques available to soil conservators. Since design details generally remain unproven as well as undocumented, this involves assembling available information on design practices, and developing a standardised method of evaluating effectiveness for particular site-treatment combinations. Effectiveness is assessed in terms of both on-site and off-site effects.

Earthflow mass movement and pasture productivity

Earthflow movement is the slow, episodic, downslope flowing of soil and underlying material. Although soil loss may not always be large, the surface of earthflows is usually broken by tension cracks and smaller secondary movements which form an irregular hump and hollow terrain. Earthflows are typically saturated and soft in the winter months, making stock access difficult. Earthflow activity lowers the productivity of large areas of fertile pastured mudstone hill country as well as damaging capital assets such as fences, tracks and buildings.

To formulate appropriate conservation policies it is essential that soil conservators, farmers, and planners have reliable information on the economic impact of earthflow activity and the effectiveness of control practices. Experimental studies in the East Cape region have quantified earthflow-induced productivity reductions and the increases in productivity which may be achieved through a range of land management strategies. Productivity reductions of 30 percent are probably widespread, while in the most disturbed areas production may be lowered by as much as 77 percent.

This loss in production is due primarily to exposure of less fertile subsoil and extremes in soil moisture content produced by irregular, broken land surfaces. Treatment by drainage and recontouring can, as well as improving stability, increase pasture production to levels 20 percent or greater than achieved on land unaffected by erosion and untreated. Pasture production can be maintained at 5500 to 6000 kg per hectare per year even where treatment consists of planting spaced willows. Work continues on methods for integrating these results into more sustainable land use strategies involving tree planting on pasture.

Impact of soil conservation

Erosion-induced damage to farmland, forest, and

watercourses has been studied on the East Coast of the North Island from 1983 to 1989, Taranaki in 1990, and the Wairarapa in 1991. These studies have shown that in the absence of soil conservation measures, damage is highly variable but can be described by binomial-type frequency distributions. These distributions, when combined with information about storm magnitude and occurrence, enable the long-term impact of erosion, from a series of storms, to be estimated. Damage levels are much lower where unstable terrain had been space planted with deciduous trees, afforested with pines, or allowed to revert to indigenous scrub.

Most previous assessments of the effectiveness of soil conservation in New Zealand have been qualitative. These new quantitative findings can be used for cost-benefit analysis of soil conservation measures by economists, government policy agencies, and the regional councils which are now responsible for soil conservation.

Land rehabilitation

Areas that are disturbed by activities such as mining generally have to be restored to an environmentally acceptable standard. Mined land can be made useful for farming, horticulture, exotic or native forest, conservation or recreation purposes. DSIR Land Resources was involved in research and consultancy to establish the most appropriate way of reconstructing land and restoring soils, particularly in native forests, after mining. Loss of fertile soil horizons, the presence of chemicals toxic to plant growth, and soil compaction by heavy earthmoving machinery are the principal factors limiting site recovery. Research has focused on land restoration following mining for lignite in Southland, gold in hard rock on the Coromandel, gold from alluvium in Westland, coal from Waikato, and gravel from Nelson.

Soil compaction, caused by heavy earthmoving equipment, is one of the major problems in the rehabilitation of land. Compaction destroys the soil structure and hinders both drainage and root growth. Techniques for using soil engineering and physical properties to predict the degree of soil compaction during mining operations, and procedures to minimise such compaction, were developed. As reconstructed soils are low in fertility, it is necessary to prescribe soil amendments and fertilisers to ensure productivity of new vegetation, whether forest or pasture species. Guidelines for managing the rehabilitation of pasture or forest ecosystems through manipulation of physical, chemical and biological constituents were provided. Plant species suitable for revegetation of disturbed sites were evaluated and catalogued.

CATCHMENT PROCESSES AND HAZARDS

Erosion, flooding and sedimentation constrain the sustainable land use and development of cyclone-prone soft rock hill country. This programme aims to improve understanding of the relationship between land use and catchment-scale erosion-

Land which has been disturbed by mining or other activities can be restored to an environmentally acceptable standard.

Debris dams and willow pole plantings are some of the techniques used to control gully erosion.

sedimentation dynamics. This information, together with the results of soil conservation research, will be used to manage the risks of land development and thereby minimise the impacts of erosion and sedimentation on primary production and the environment.

Erosion history of Lake Tutira catchment

Nearly half of New Zealand's land area is made up of hill country underlain by geologically young "soft" rocks prone to severe erosion. Major storms such as Cyclone Bola cause this land to slide downhill destroying farms, water supplies, roads and other resources - at great cost. Such storms are certain to reoccur, so identifying land use strategies which minimise erosion in hill country is important to land owners, local authorities and the wider community.

Effective management of environmental risk relies on accurate prediction of how land responds to natural events like storms and human intervention such as deforestation. The basis for such predictions in any area is the erosion history recorded in sediments deposited in layers in the valleys and lake beds. Examination of lake cores taken from the Tutira catchment, northern Hawke's Bay, revealed that it is possible to correlate storm events with 'pulses' of sediment of varying thickness. The cores provide a dramatically detailed representation of individual storms. So that, for the first time, it is possible to measure accurately the way the landscape has responded to storms over the last few thousand years. It is therefore possible to quantify the impacts of pre-Polynesian, Polynesian and European intervention and associated vegetation changes, and relate storms size to the volume of sediment produced. Future work will build predictive models which can be calibrated with the Tutira record, so the implications of different land use decisions can be explored and the hazards and risks evaluated.

Landslide erosion and land productivity

Pasture productivity in New Zealand is slowly, but steadily declining. This problem is particularly serious in storm-prone hill country where few farmers can afford the necessary inputs, especially fertilisers, to bolster diminishing production levels. The decline in productivity in these areas is mainly due to loss of nutrient rich topsoil through landslides. Continued pastoral use, deforestation, and cyclonic storms all affect the extent of such erosion.

Research was undertaken to further the understanding of the relationship between hillslope pasture production and landslide erosion. Productivity loss associated with this erosion was quantified by measuring pasture growth rates on landslides of different ages and on cleared but stable remnant forest soils. Pastoral development

Landslide and sedimentation damage in the Lake Tutira area after Cyclone Bola in 1988.

results in shallower soils, and soil depth is further reduced as the hillside becomes steeper. The effects of storm damage vary according to land use, with more erosion occurring under pasture than under either pine forest or native forest. Faster recovery of landslide scars to productive pasture can be encouraged with the right combination of land use, pasture species, and fertiliser application.

This research has laid a good foundation for the development of land management techniques leading to more sustainable land use. A practical extension has involved developing and evaluating a management plan for achieving the physical sustainability and economic viability of a Taranaki farm. The plan, devised in collaboration with the Taranaki Regional Council, Ministry of Agriculture and Fisheries and the farmer concerned, is based on intensifying management on the best land, progressively destocking the poorest and steepest land and planting forest on some suitable areas.

Flooding and sedimentation hazards

A pilot study was undertaken to describe the long-term evolution of the Wairau Plains, Marlborough, and to determine the factors controlling its evolution. This study demonstrates that it is possible to use soils and geomorphological dating techniques as a basis for zoning the plains according to the degree of flood hazard. Radiocarbon dates and soil pattern analysis were used to estimate the age of the floodplain and terrace surfaces and hence the time since the last major flooding. This information is used to develop an understanding of river behaviour and assess the degree of hazard in different parts of the floodplain. Likely future changes to the floodplain in the short and medium term can be predicted taking account of the occurrence of large floods, water course changes, climate change, sea level rise, and earthquakes. The aim of the study is to develop nationally applicable methods for cost-effective flood hazard mitigation that take account of the geomorphic factors controlling river behaviour and realistically consider the impact of large, but infrequent, floods.

Tephra dating and land stability

Tephra, the solid materials explosively ejected during a volcanic eruption, consists of boulders, ash and lapilli or tephra pebbles. Volcanic activity in the past has periodically deposited tephra over the New Zealand landscape. As a result, layers of tephra are now found at varying depths in soils throughout New Zealand. These tephra layers can be dated and their relative depth then used to show the degree of weathering and erosion that has occurred over the period of time since they were deposited.

A database of tephras deposited during the last 400 000 years has been compiled and forms a basis for determining the magnitude and frequency of volcanic eruptions. This database has proven invaluable for providing time planes for determining erosion and sedimentation rates related to natural phenomena and human intervention. Tephra layers were used to date sediments and land surfaces to establish erosion history at Lake Tutira in Hawke's Bay and at Makahu in Taranaki.

Resource Assessment and Evaluation

NEW ZEALAND LAND RESOURCES AND THEIR SUSTAINABLE USE

Quality information about New Zealand's finite land resources is necessary for planning economic and ecologically sustainable land uses. Land resource data such as landforms, vegetation, soils, regolith, and other land qualities is gathered and integrated. Land assessment methods and models are developed to establish the relationship between land attributes and specific land use suitabilities within different natural environments and productive systems. These data are used for making land resource assessments of areas with pressing land use and management problems. Information and technology is transferred to scientists, planners, managers and the public to improve understanding of natural values and of sustainable land use management.

Soil classification

Modern and practical methods for describing and classifying land and soil resources are being developed. Ultimately this will facilitate more informed approaches to land use by ensuring standardisation of baseline soil resource information.

An innovative *Soil Description Handbook* which contains standardised descriptions of soil and site features was published in 1991 and a revised scheme of soil horizon notation in 1989. These publications facilitate more comprehensive and quantitative soil description in the field and are designed for computer database applications.

The *New Zealand Soil Classification* (NZSC), published in 1992, is based on many years of research and development. It replaces the New Zealand Genetic Soil Classification, introduced in 1948, which is not precise enough for modern land evaluation systems. The new system consists of 15 soil orders, each of which is divided successively into soil groups and subgroups. It is an efficient tool for soil identification in soil survey and facilitates communication about New Zealand soils.

Soil subgroups identified in the NZSC will be split into a further category, which approximates the existing soil series concepts. This further level of classification identifies soil profiles more precisely and can be used on soil maps at scales of 1:50 000 or larger. Criteria for defining the new soil series within subgroups are being developed and tested.

Land resource inventories and assessment

The New Zealand Land Resource Inventory (NZLRI) is a national database containing information on rock type, soil unit, slope, erosion and vegetative cover throughout New Zealand. These factors vary in different areas, but all have some influence, whether singly or in combination, on slope stability and future land use potential. By combining these factors with climate information and effects of past land use, the capability of land for permanent and sustained production can be assessed and classified as one of eight land use capability classes. This information is used for soil conservation management and land use planning.

Work is underway to upgrade land resource inventory information for the Marlborough and West Coast regions and resource inventories were prepared for Northland and Wellington. Soil survey reports were completed for Hauraki Plains, part Matamata County, Otaki district and the Te Kawa irrigation district and the Waikato lowlands. Soil information was also compiled for part Tauranga County and two hill country sequences in Wairarapa, southern Hawke's Bay.

Traditional approaches to land resource mapping and assessment are time consuming and expensive. Considerable field work and analysis is required to map soils and landforms for a particular area. This information must then be compiled and interpreted so that land use and development recommendations can be made.

Alternative techniques and procedures to efficiently map and evaluate land resources are being investigated. A method for predicting soil distribution from landscape features is being developed. The technique is based on the concept that soil distribution is related to landforms, geology, climate, and vegetation. Using this logic it is possible to extrapolate from identified landforms to predict soil distribution. A framework for such analysis is being constructed from existing soil surveys and detailed analysis of representative areas. Land is first classified into areas with similar physical properties which are then divided into smaller more homogenous classes through several categories of classification. Soil distribution, type and land use capability can be rapidly identified, with limited field work, by systematically following a series of keys.

This approach is being investigated for mountain and lowland areas in the Canterbury region. The technique is being combined with advanced technologies such as digital terrain models and satellite imagery in the Gisborne-East Cape region. This research will assist the planning for sustainable land uses at national, regional and district level.

Land use suitability studies

Over 200 000 hectares of land in Otago and Southland, excluding Central Otago have soils with horticulture potential. This large area of land could

Land resource information is gathered by airphoto interpretation and fieldwork. Awatere Valley, inland Marlborough.

be more intensively used for horticultural crops requiring or tolerating cool temperate conditions. To assist land users and investors to use these soils in a scientific and sustainable way, guides were prepared on the soils of horticultural potential in the Southland, coastal Otago, Waitaki Valley, and Kakanui districts. The guides are illustrated in full colour and publication costs were shared with Ravensdown Fertiliser Cooperative Ltd.

Many high country farmers in North Otago and South Canterbury face rabbit, *Hieracium* and land management problems. A detailed map of the Tara Hills high country research station at Omarama, showing the distribution of soils, was produced jointly with the Ministry of Agriculture and Fisheries. Areas of low altitude land with deep and fertile soil suitable for forestry have been identified. Soils which may be prone to acidification and land which is most appropriately left in tussock grassland vegetation were also identified. Because the Tara Hills property is typical of North Otago and South Canterbury high country, recommendations can be extrapolated to other locations with similar landform and climate.

Soils of the hill country east of Gore and in the Hokonui Hills and Waimea Plains northwest of Gore were mapped to provide better information for possible horticultural and forestry development. In recent years there has been considerable interest in eucalypt forestry in the hill country and in bulb production on the high class arable soils in the Gore district. To stimulate such new land uses, and to provide a scientific basis for land use planning in the district, two maps were produced in digital format. Using a Geographic Information System, a database of attributes, such as fertility and slope, is being compiled for each soil. The ability of the GIS to make land use interpretations based on the soil map plus database, extends the usefulness of traditional soil mapping.

The downlands of Canterbury and North Otago (occupying an area in excess of 200 000 hectares) are an environmentally sensitive landform used for cropping. Soil-landscape models, which relate landscape position, soil properties and susceptibility to erosion, are being developed in this area in conjunction with a study of erosion rates. This work will provide a basis for assessing the extent of land degradation under cropping and for making recommendations on cultural practices to conserve the soil resource.

Detailed soil variability studies on extensive drought-prone shallow soils of the Canterbury Plains will provide land users with knowledge of

soil variability expected within management units. This information will enable better management decisions to be made, for example, amounts and frequency of irrigation. Understanding of soil variability is also needed to provide accurate information for use in models which calculate groundwater recharge and the propensity of land to pollute groundwater.

LAND RESOURCE DATABASES AND INFORMATION SYSTEMS

This programme is responsible for maintaining national databases and for development and application of Geographic Information Systems (GIS) and remote sensing/image processing technologies. This programme has its historical roots in work stretching back over the last 15 years in the former Water and Soil Directorate of Ministry of Works and Development and the former Soil Bureau and Science Mapping Unit of DSIR. Major parts of this programme are currently based on the Taita, Aokautere and Lincoln campuses of DSIR Land Resources.

Database maintenance and quality assurance

DSIR Land Resources maintains two major national land resource databases - the New Zealand Land Resource Inventory (NZLRI) and the New Zealand National Soils Database (NSDB). The NZLRI is a single digital map of the whole country at a 1:50 000 scale. Information on slope, soil, rock type, vegetation, erosion and land use capability is recorded for each map unit or polygon. Additional information, for example, stock carrying capacity, is recorded for each land use capability class. This database is used to produce maps of any attribute which is recorded or can be inferred from this data. The maps may be produced for any part of the country and at any scale up to the nominal 1:50 000 scale (maps can be produced at larger scales but will not have appropriate spatial resolution).

The National Soils Database comprises detailed soil descriptions and laboratory analyses for almost 2000 fully characterised soil profiles. Unlike the NZLRI, it does not give a complete spatial coverage of the country and, in fact, each profile only relates directly to the point at which it was described. The information recorded for each profile is, however, comprehensive and may be extrapolated via a soil map or the soil data of the NZLRI. To facilitate this extrapolation the database has additional files storing information about soil classes and the surveys and regions in which they were mapped. These files provide a link between soil maps and the detailed profile descriptions.

Apart from maintaining the databases, delivering the information to users in an appropriate format is an important component of this work. These users may be other science programmes or commercial clients. The data provided may be hardcopy maps or tabular printouts, detailed reports accompanied by maps and tables or digital data to be manipulated by the user. Current research involves the development of automated procedures for efficiently producing the required wide range of outputs while maintaining appropriate cartographic and scientific standards.

Database integration

Databases held by DSIR Land Resources are being integrated. The immediate focus is on integration of the National Soils Database (NSDB) and the New Zealand Land Resource Inventory (NZLRI) so that the detailed soil information in the former can be effectively combined with the complete spatial coverage of the latter. The soil names used in the two databases have been correlated and information extracted from the soils database is now directly accessible from the NZLRI. Similarly the soil data from the NZLRI has been exported to a PC system which allows it to be related to any attributes ascribed to the soil classes. About half the soil class names used in the NZLRI are represented in the NSDB. Information for other classes may be inferred from a list of similar soil names (part of the NSDB) or from the higher level NZ Genetic Soil Class to which the soil belongs.

The second approach to database integration is the compilation of a soil "knowledge base" which will contain a set of attributes assessed for each soil name used in the NZLRI. This assessment will be based on information in the NSDB and on the expert knowledge of the people making the assessment. The attributes assessed will be those influencing land use such as, drainage class, soil water storage capacity, permeability, and rooting volume.

Future work is expected to widen the scope of database integration to include other reference collections. This will be particularly important where a common spatial framework is required and where different types of information, for example soil and vegetation, need to be combined.

Crop modelling

Computerised systems which evaluate the suitability for land for major crops are being developed. These evaluation systems may be based on crop growth simulation models or on simpler decision tree models or classification schemes. The models may be purely physical, such as crop yield and sustainability, or economic such as gross margin.

Maps showing the relative suitability of land for various uses are constructed using Geographic Information Systems which link models with spatial data such as soil and climate. This information then provides a basis for land use planning and management decisions. Evaluation systems investigated to date, include quantitative

production models for wheat, pasture, *Pinus radiata*, apples, and generalised assessment schemes for horticulture and irrigation suitability.

Climate terrain modelling

Digital terrain data consist of a matrix of numbers representing height of land at set points on the landscape. Information stored in digital format is highly compatible for computer storage and analyses and can be used to produce detailed three dimensional images and maps. The resolution or scale of maps produced from digital terrain data is determined by the distance between altitude measurements, for example a 100 metre digital terrain model (DTM) gives spatial resolution equivalent to about a 1:100 000 map scale. A 100 metre resolution DTM for the North Island and finer 20 metre DTMs for several smaller areas, based on existing contour information, have been generated. A 100 metre DTM for the South Island will be produced as soon as digital contours are available.

DSIR Land Resources, in collaboration with the New Zealand Climate Centre, is developing predictive models of spatial climate variation using digital terrain data. Terrain is the major factor controlling climate patterns at scales of about 1:250 000 or larger. The terrain-based models enable us to produce much more detailed maps of (predicted) climate variables such as rainfall, temperature, radiation and evapotranspiration.

The relationship between factors such as elevation, latitude, distance from coast, directional "rain shadow" and "shelter gradients", and climate data has been modelled. Predictions of mean annual air temperature and 10 and 15 degree thermal times for the whole year and for the "growing season" were produced. Unfortunately climate stations are almost invariably located on flat sites so it is not possible to determine the effect of slope and aspect statistically from the climate data. We hope to model these effects using theoretical models from New Zealand Climate Centre.

Investigation of more complex models of cold air drainage and resultant frost susceptibility are in progress using more detailed 20 metre DTMs of a pilot area in Central Otago. This work will be developed further in future years along with completion of the national 100 metre DTM and resultant climate database and research on satellite images to measure and predict cloud cover and hence refine other climate models.

Digital landscape modelling

DSIR Land Resources aims to develop automated or semi-automated techniques to apply landscape models to detailed soil and land resource mapping based on digital terrain models (DTMs). A method for constructing high resolution DTMs from existing digital contour information has been developed. From these DTMs, parameters such as slope, aspect and earthflow accumulation areas, can be calculated. A further application involved generating a "soil map" directly from the DTM by developing a landscape model to predict soil distribution from landscape features.

Three dimensional or stereoscopic images are needed to assist with interpreting and mapping landscape features. Traditionally these are created by viewing two adjacent photos through a stereoscope. DSIR Land Resources has developed a PC based system which displays landscape features on a computer monitor. When the viewer wears a pair of red and green glasses the landscape can be seen in three dimensions. This facility is currently only available in monochrome but work is underway to produce a full-colour system.

Remote sensing

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through analysis of data acquired from a device that is not in contact with the object, area, or phenomenon under investigation. Remote sensing devices are normally either cameras or scanners mounted in satellites and aircraft. Information is obtained from remotely sensed images by visual, or computerised methods which assist image interpretation. Some computer systems enable the integrated use of remote sensing image processing, Geographic Information Systems, and digital terrain models so that a range of spatial data types can be used to find solutions to land management and environmental problems.

Remote sensing techniques are a valuable tool for land resource mapping and land management and have been developed for a range of applications, including: surveys of mass movement erosion and sedimentation caused by cyclones or rainstorms; mapping of agricultural and forest vegetation types; mapping vegetation stress caused by browsing or disease; determining the percentage vegetation cover in semi-arid landscapes of the South Island; detecting changes in land use and land cover by using time-sequential digital data from aerial photographs and satellite data; and combining data from remote sensing-image processing and Geographic Information Systems to produce high quality maps.

DSIR Land Resources was involved in a large number of remote sensing consultancies. Major clients include Department of Conservation, Ministry of Forestry, regional councils, and catchment boards. Most overseas work was conducted in Fiji and Iran. Staff were also involved in technology transfer and training activities.

Future work will involve the development of more accurate methods of obtaining information from digital remotely sensed images, further integration of spatial information systems for land

Landsat satellite image showing agricultural crops and pastures, shelter belts, forestry, roads and river patterns of part of the Manawatu region. (Photo: © EOSAT 1990).

Degraded tussock grasslands in the MacKenzie Basin.

evaluation and resource monitoring purposes, and the use of small scale weather satellite images for a pasture production prediction and cloud cover assessments.

SUSTAINABLE USE OF TUSSOCK GRASSLANDS

More than three million hectares of tussock grasslands in the high country of the eastern South Island have degraded soils and vegetation. DSIR Land Resources is contributing to the identification of more sustainable land use options for these lands. Work is being undertaken to describe and quantify the land resources across the high country landscape. The nature of land degradation and adverse impacts of management are being investigated and land restoration techniques are also being evaluated. This research has direct links with the Department of Conservation, Forest Research Institute, regional councils, farmers, Landcorp and Ministry of Agriculture and Fisheries.

Land and climate resources

Initially, research emphasis is being placed on the dry, degraded tussock grasslands in Central Otago and the Waitaki basin. In a detailed study of a semi-arid landscape in Central Otago, relationships are being established between landforms, vegetation, rabbit populations and key properties of soils, including bulk density and organic carbon content. These relationships will be used to assess the status of land degradation for planning rehabilitation of soils and vegetation.

Databases of information about land (e.g., landforms, soils, vegetation and climate) and land management (e.g., land use, agronomic research trials and farmer experience) are being compiled for representative land areas in the Waitaki Valley in South Canterbury. This includes contrasting landscapes, ranging from semi-arid to very wet, and basins to high mountains. Interactions between land management practices and the environment are being studied so that the most appropriate management options can be identified.

Impacts of management on vegetation and soils

Although the adverse effects of overgrazing and repeated burning on soils and vegetation have long been recognised, determination of sustainable levels of grazing and frequencies of burning, in a range of environments, has remained largely elusive. In response to concern about impacts of grazing sheep and rabbits in dry grasslands, a long-term programme to monitor trends in grasslands in the Waitaki basin has been established by Forest Research Institute, in association with DSIR Land

Resources, Department of Conservation and Ministry of Agriculture and Fisheries. After two years without grazing, tussock grasses and shrubs are larger and native and introduced herbs have begun to colonise bare ground. Hawkweeds are particularly aggressive and may be suppressing native plants. In the contrasting wet, alpine grasslands near the main divide, a field survey has shown that the dominant snow tussock grasses have endured low levels of grazing for up to 25 years, whereas these species have been replaced by short-stature grasses in areas of more concentrated grazing.

Some mid to high altitude tall tussock grasslands in Otago, used for seasonal, low intensity grazing, are burnt periodically in the spring to remove litter cover to induce nutritious new growth and to improve stock access. The relative recovery of snow tussock after fire is being investigated at a range of sites where the time since last burning is known and where the recovery of tussocks is considered to be satisfactory. Some relatively easily measured attributes of tussocks, for example, tiller length and weight and tussock basal area, which can signal recovery, have been identified. A sampling index that can be used by land managers to assess whether or not a particular tussock grassland could sustain burning is being derived.

Effects of grassland fires on soils are mainly confined to the near surface layers, especially the organic matter and fauna. A comparative study in progress on the Old Man Range at unburnt and recently burnt sites shows marked changes in soil carbon and phosphorous cycles due to the effects of fire on the vegetation. Results from this research are being used to develop indices of recovery and models which will help to prescribe guidelines for the sustainable use of burning.

Land restoration

Adverse soil conditions and climate constrain the restoration of degraded tussock grasslands. DSIR Land Resources is contributing to land restoration research by examining the potential role of indigenous species of trees, shrubs and grasses. Many of the degraded grasslands have historically supported woody vegetation. Combinations of grassland and shrubland, including the use of native nitrogen-fixing shrubs like matagouri, are being explored. When plant competition was controlled, a range of native tussocks, shrubs and trees have performed well in dryland trials in Canterbury. However, pines and eucalypts are generally faster to establish. The best performing species in lowland and montane environments include: coprosmas, kanuka, olearias, cabbage tree and pittosporums.

In association with Landcorp, the natural recovery of destocked semi-arid grasslands in a sequence of exclosure plots near Alexandra, Central Otago, was evaluated. Cessation of grazing resulted in an overall increase in the number of perennial plants, including cocksfoot, ryegrass and kentucky bluegrass, at the expense of annuals such as subterranean clover, storksbill and hawksbeard.

Pot trials and field experiments show that mouse-ear hawkweed, an aggressive, weedy species in degraded tussock grasslands, competes more vigorously with low-growing native species when soil fertility is high, but its competitiveness is reduced by shading. These results may strengthen the value of tall, woody species in this environment.

In collaboration with DSIR Grasslands, keys to the selection of pasture species for high country environments are being developed according to the variability in soil conditions (especially depth, stoniness and drainage) and climate (particularly rainfall and temperatures). Required management inputs and estimated production yields are indicated. This work has drawn on an extensive pool of available results from agronomic trials and should generate substantial production as well as land restoration benefits.

URBAN AND RURAL PLANNING

The programme researches and develops land evaluation methodology and Geographic Information System (GIS) technology as 'tools' for data collation and manipulation for urban and rural land use planning. The research was conducted as a series of pilot studies at selected locations and has potential for district, regional and national applications.

Users of information demand a more comprehensive research product. GIS technology and associated traditional methods provide the means to integrate data sources important for decision making to resolve conflicting demands for reduced and sensitive resources at the rural-urban interface.

Integrated land use planning

The basis for a predictive soil-landscape model was developed. When completed this model will be able to predict soils at unknown sites based on factors such as elevation, aspect and parent material. This will reduce labour intensive and costly field work and allow more rapid identification of soil suitability for land use practices such as horticulture, forestry and urban development. As part of this work a Digital Elevation Model, with a 20 metre contour interval, was constructed for Banks Peninsula in Canterbury. This three-dimensional terrain model allows calculation of slope, aspect and elevation, from which it is possible to derive factors such as the duration and intensity of sunlight and drainage for any point in the landscape. This, and other biophysical information can be used to identify areas suitable for native revegetation programmes, housing sites or roading.

A soil survey report for the Port Hills (Canterbury) was completed with an accompanying map at 1:10 000 scale. This report identifies types of soils and their chemical and physical properties. The soil types were interpreted for their potential for urban, agricultural, forestry and horticultural use. Soils currently or likely to become erosion hazards were also identified.

GIS and property valuation

A pilot study was undertaken in which data from the Department of Survey and Land Information (DOSLI) was integrated with a Valuation New Zealand (VNZ) database for part of Ashburton District using a GIS. The DOSLI database (Digital Cadastral Database) contains information on land parcels throughout New Zealand with respect to their geographic location, shape, area and legal description. The VNZ database holds property information such as government valuation records and sale information. Property boundaries may contain more than one land parcel, particularly in rural areas. By linking the two databases information is made available on land area, capital value, land use and improvements for each farm.

These farm boundaries were overlain with biophysical data such as soil and crop suitability maps. This will enable analysis of the relationships between land value and sale price with land use and land capability. The results will be of vital interest to valuers, real estate agents, and could influence how rating systems evolve in rural areas in future. This research is unique to New Zealand as nowhere else are such databases publicly available in a form which makes these types of analyses possible.

Land evaluation systems for the urban fringe

Urban expansion into rural areas is occurring rapidly throughout New Zealand. Clearly some land is inappropriate for housing development because of flooding risks or because it supports high quality soils suitable for crop production. Under the terms of the Resource Management Act (1991), land must be used in a way that is sustainable, i.e., will benefit future generations. None of the major existing land evaluation approaches (e.g., soil survey, engineering, geological, and urban land use capability) provide an objective method of land evaluation which takes into account the restrictions of this Act.

A comprehensive report was completed which outlines approaches to evaluating land for urban use, and argues for a more formal, rule-based approach to land evaluation in New Zealand. The new approach is a natural extension of the urban land use capability method which is increasingly favoured among planning staff requiring of tools which assemble and integrate the information necessary for urban fringe planning.

Future work will build on this framework to develop the rule-based system and pilot its application in Manukau City. This city is ideal for trialing the system as it is one of the fastest growing cities in New Zealand and is surrounded by high quality soils ideal for food production.

South Island land resource information

A land use planning tool is now available for the South Island containing information on soils, vegetation, geology, slope, erosion and land use capability. This information was compiled at a base scale of 1:50 000 in a GIS following the format of the New Zealand Land Resource Inventory held at Taita. Work is continuing on expanding the data held for soils, by including information from detailed soil surveys in the South Island. At a later date vegetation and slope information will also be upgraded.

Once compiled in the GIS, map production systems were developed to enable analysts to respond, in a timely manner, to requests for information from anywhere in the South Island.

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DSIR Land Resources Publications

Aldridge, L.P.; Churchman, G.J. 1991: The role of iron in the weathering of a climosequence of soils derived from schist. *Australian journal of soil research*. 29:387-398

Allen, R.B. 1991: A preliminary assessment of the establishment and persistence of *Berberis darwinii* Hook., a naturalised shrub in secondary vegetation near Dunedin, New Zealand. *New Zealand journal of botany*. 29(4):353-360

Allen, R.B.; Lee, W.G. 1992: Fruit selection by birds in relation to fruit abundance and appearance in the naturalised shrub *Berberis darwinii*. *New Zealand journal of botany*. 30(2):121-124

Allen, R.B.; Partridge, T.R.; Lee, W.G. 1992: Ecology of *Kunzea ericoides* (A. Rich.) J. Thompson (kanuka) in east Otago, New Zealand. *New Zealand journal of botany*. 30(2):135-149

Allen, R.B.; Wilson, J.B. 1991: A method for determining indigenous vegetation from simple environmental factors, and its use for vegetation restoration. *Biological conservation*. 56(3):265-280

Allen, R.B.; Wilson, J.B. 1992: Fruit and seed production in *Berberis darwinii* Hook., a shrub recently naturalised in New Zealand. *New Zealand journal of botany*. 30(1):45-55

Anderson, A.J.; McGlone, M.S. 1991: Living on the edge - prehistoric land and people in New Zealand. *In*: Dodson, J. (*ed.*). Prehistory and environmental change in Australia and the south-west Pacific. Longman Cheshire, Melbourne. p. 199-241

Andreux, F.; Theng, B.K.G. 1990: Organic sources of nitrogen and phosphorus nutrients in humus-rich soils with variable charge. Transactions, 14th International Congress of Soil Science, Kyoto, Japan, August 1990. Volume II, Commission II:180-185

Arand, J.; Basher, L.; McIntosh, P.; Heads, M. 1991: Inventory of New Zealand soil sites of international, national and regional significance. Part one, South Island and southern offshore islands (1st edition). (New Zealand Society of Soil Science occasional publication; 1). 158 p. New Zealand Society of Soil Science.

Atkinson, I.A.E. 1990: Mapping and classifying vegetation in the Galapagos Islands, some considerations. *In*: Lawesson, J.E.; Hamann, O.; Rogers, G.; Reck, G.; Ochoa, H. Botanical research and management in Galapagos. (Monographs in systematic botany from the Missouri Botanical Garden; 32). Missouri Botanical Garden, St. Louis. p. 101-115

Atkinson, I.A.E. 1990: Ecological restoration on islands: prerequisites for success. *In*: Towns, D.R.; Daugherty, C.H.; Atkinson, I.A.E. Ecological restoration of New Zealand islands: papers presented at conference on ecological restoration of New Zealand islands, University of Auckland, 20-24 November 1989, Auckland, New Zealand. (Conservation sciences publication; 2). Department of Conservation, Wellington. p. 73-90

Atkinson, I.A.E.; Blaschke, P.M. 1991: Vegetation. *In*: Milne, J.D.G.; Clayden, B.; Singleton, P.L.; Wilson, A.D. Soil description handbook. DSIR Land Resources, Lower Hutt. p. 26-33

Atkinson, I.A.E.; Millener, P.R. 1991: An ornithological glimpse into New Zealand's pre-human past. *In*: Acta XX Congressus Internationalis Ornithologici, Christchurch, New Zealand, 2-9 December 1990. Volume I. New Zealand Ornithological Congress Trust Board, Wellington. p. 127-192

Atkinson, I.A.E.; Moller, H. 1990: Kiore *Rattus exulans*. *In*: King, C.M. (*ed.*). The handbook of New Zealand mammals. Oxford University Press, Auckland. p. 175-192

Ballance, A. 1990: In the radio business. *Resource research*. 20:5

Barker, P.R.; Stephenson, W.R. 1991: The seismic CPT probe as a tool for predicting seismic response of flexible sediments. *In*: Pacific Conference on Earthquake Engineering, Auckland, New Zealand, 20-23 November 1991, Proceedings, Volume 3. New Zealand National Society for Earthquake Engineering, Wellington. p. 181-190

Barringer, J.R.F.; Trangmar, B.B.; Salinger, J.; Porteous, A. 1991: Climate change, soil moisture deficits and wheat yields on the Canterbury Plains. *New Zealand agricultural science*. 26:44

Basher, L.R. 1990: Soil and landscape processes. *In*: Climate change: impacts on New Zealand; implications for the environment, economy and society. Ministry for the Environment, Wellington. p. 34-37

Basher, L.R. 1991: The impact of climate change on soils and landscape processes. *Weather and climate*. 11:145-149

Basher, L.R.; Floate, M.J.S.; Watt, J.P.C. 1992: Biophysical sustainability - working with nature. *New Zealand Soil News*. 40(2):51–58

Beecroft, F.G.; Hewitt, A.E.; Smith, S.M. 1991: Soils of the Taieri Plain, northeast of the Taieri River, Otago, New Zealand. DSIR Land Resources scientific report; 17. 65 p. DSIR Land Resources, Lower Hutt.

Beever, J.E. 1990: [Book review]: Under foot: *The forest carpet*, by Bill and Nancy Malcolm. *Listener*. 127(2618):110

Beever, J.E. 1990: The mosses of Miners Cove, Great Barrier Island, northern New Zealand. *Records of the Auckland Institute and Museum*. 27:155-164

Beever, J.E. 1990: Mosses of Hukatere Scenic Reserve. *Journal / Auckland Botanical Society*. 45(2):50-51

Beever, J.E. 1990: Sandflies and sphagnum - a report on the 7th John Child Bryophyte Workshop, Bordland Lodge, Fiordland, 15-20 November 1990. *Newsletter / New Zealand Botanical Society*. 22:21-22

Beever, J.E. 1991: Mosses of Tawhiti Rahi, Poor Knights Islands, northern New Zealand. *Records of the Auckland Institute and Museum*. 28:201-210

Beever, J.E. 1991: A moss list for Moturemu Scenic Reserve, Kaipara Harbour. *Journal / Auckland Botanical Society*. 46:10-11

Beever, J.E. 1991: Mosses of Tapu Bush and Pretty Bush, Kaipara North Head. *Journal / Auckland Botanical Society*. 46:73-74

Beever, J.E. 1992: Mosses of Motukaraka (Flat Island). *Journal / Auckland Botanical Society*. 47: 18-19

Beever, J.E. 1992: Taxonomic notes on two New Zealand mosses: *Bryobartlettia costata* Buck (Fabroniaceae) and *Calliergon laxirete* Zant. et Bartlett (Amblystegiaceae). *New Zealand journal of botany*. 30:205-206

Beever, J.E.; Brownsey, P.J. 1990: Mosses of Whale Island (Motuhora), Bay of Plenty, New Zealand. *Tane*. 32:49-60

Beggs, J.R. 1991: Altitudinal variation in abundance of common wasps (*Vespula vulgaris*). *New Zealand journal of zoology*. 18(2):155-158

Beggs, J.R.; Alspach, P.A.; Moller, H.; Toft, R.J.; Tilley, J.A.V. 1992: Impacts of the parasitoid *Sphecophaga vesparum* on colonies of the common wasp (*Vespula vulgaris*). Proceedings of the 41st Conference. Entomological Society of New Zealand.

Beggs, J.R.; Moller, H. 1991: New Zealand wasp research - uncoordinated goals or still stuck in the descriptive bottle neck? *New Zealand journal of zoology*. 18:230-231

Beggs, J.R.; Wilson, P.R. 1991: The kaka (*Nestor meridionalis*), a New Zealand parrot endangered by introduced wasps and mammals. *Biological conservation*. 56:23-38

Blackburn, N.; Taylor, R.H.; Wilson, P.R. 1991: An interpretation of the growth of the Adelie penguin rookery at Cape Royds, 1955-1990. *New Zealand journal of ecology*. 15(2):117-121

Blaschke, P.M. 1990: Vegetative indicators of erosion frequency. *In*: Zeimer, R.R.; O'Loughlin, C.L.; Hamilton, L.S. International Association of Hydrological Sciences, Research needs and applications to reduce erosion and sedimentation in tropical steeplands: procceedings of the Fiji Symposium, June 1990. (IAHS-AISH publication; 192). IAHS Press, Wallingford, Oxfordshire. p. 385

Bloor, S.J.; Molloy, B.P.J. 1991: Cytotoxic norditerpene lactones from *Ileostylus micranthus*. *Journal of natural products*. 54(5):1326-1330

Bongers, T.; Alkemade, R.; Yeates, G.W. 1991: Interpretation of disturbance-induced maturity decrease in marine nematode assemblages by means of the Maturity Index. *Marine ecology progress series*. 76:135-142

Brockie, R. 1990: Black death strikes national icon [cabbage tree death]. *The Examiner*. 15 Nov. 1990:17

Brockie, R. 1991: The final solution? [rabbit control]. *New Zealand science monthly*. 2(2):8-11

Brockie, R.E. 1991: Hedgehogs. Ecology notes; 22. 2 p. DSIR Land Resources, Lower Hutt.

Brockie, R. 1991: Ecology of an uninfected farm possum population. Symposium on tuberculosis. Publication / Veterinary Continuing Education, Massey University. 132:53-66

Brockie, R. 1992: A living New Zealand forest. David Bateman Ltd., Auckland. 172 p.

Brown, L.J.; Tuohy, M.P.; Stephens, P.R. 1990: Integrating some PC packages for image processing, GIS and terrain modelling. Proceedings 2nd Colloquium of the Spatial Information Research Centre, University of Otago, New Zealand. November 28-30, 1990.

Bulfin, M.J.A. 1990: [Book review]: Rarer: *Threatened plants of New Zealand*, by Catherine M. Wilson and David R. Given. *Listener*. 127(2623):111-112

Cassie-Cooper, V. 1990: [Book review]: *The diatoms: biology and morphology of the genera*. Round, F.E.; Crawford, R.M.; Mann, D.G. 1990. Cambridge, Cambridge University Press. 747p. *New Zealand journal of marine and freshwater research*. 24:577-581

Cassie, V. 1991: Micro-algae of thermal areas. *In*: Clarkson, B.D.; Smale, M.C.; Ecroyd, C.E. Botany of Rotorua. Forest Research Institute, Rotorua. p. 73-78

Chapman, J.A.; Flux, J.E.C. 1990: Introduction and overview of the lagomorphs. *In*: Rabbits, hares, and pikas: status survey and conservation action plan. IUCN, Gland, Switzerland. p. 1-6

Chapman, J.A.; Flux, J.E.C. 1990: Lagomorph classification. *In*: Rabbits, hares, and pikas: status survey and conservation action plan. IUCN, Gland, Switzerland. p. 7-13

Chapman, J.A.; Flux, J.E.C. 1990: The hares and jackrabbits. *In*: Rabbits, hares, and pikas: status survey and conservation action plan. IUCN, Gland, Switzerland. p. 61-94

Chapman, J.A.; Flux, J.E.C. 1990: The Sumatran rabbit *Nesolagus netscheri*. *In*: Rabbits, hares, and pikas: status survey and conservation action plan. IUCN, Gland, Switzerland. p. 137-139

Chapman, J.A.; Flux, J.E.C. 1990: Exotic populations. *In*: Rabbits, hares, and pikas: status survey and conservation action plan. IUCN, Gland, Switzerland. p. 147-153

Chapman, J.A.; Flux, J.E.C. 1990: Conservation action needed for rabbits, hares, and pikas. *In*: Rabbits, hares, and pikas: status survey and

conservation action plan. IUCN, Gland, Switzerland. p. 154-167

Childs, C.W.; Lepsch, I.F. 1991: The nature of iron in basaltic Oxisols, as shown by Moessbauer spectroscopy: examples from Innisfail, North Queensland. DSIR Land Resources scientific report; 6. 62 p. DSIR Land Resources, Lower Hutt.

Childs, C.W.; Matsue, N.; Yoshinaga, N. 1990: Ferrihydrite deposits in paddy races, Aso-Dani. *Clay science*. 8:9-15

Childs, C.W.; Matsue, N.; Yoshinaga, N. 1991: Ferrihydrite in volcanic ash soils of Japan. *Soil science and plant nutrition*. 37:299-311

Childs, C.W.; Parfitt, R.L.; Newman, R.H. 1990: Structural studies of silica springs allophane. *Clay minerals*. 25:329-341

Childs, C.W.; Whitton, J.S. 1990: A proposed revision of the key to mineralogy classes of soil taxonomy (1975). *In*: International Congress of Soil Science, 14th, 1990. Kyoto, Japan, Transactions, 14th International Congress of Soil Science, Kyoto, Japan, August 1990, Volume VII. 459p. International Society of Soil Science, Kyoto, Japan. p. 10-15

Churchman, G.J.; Burke, C.M. 1991: Properties of subsoils in relation to various measures of surface area and water content. *Journal of soil science*. 42:463-478

Churchman, G.J.; Burke, C.M.; Parfitt, R.L. 1991: Comparison of various methods for the determination of specific surfaces of subsoils. *Journal of soil science*. 42:449-461

Churchman, G.J.; McIntosh, P.D.; Burke, C.M.; Whitton, J.S. 1991: Clay mineralogy of soils formed on tuffaceous greywacke, Southland, New Zealand, in relation to genesis, soil properties and classification. *Australian journal of soil research*. 29:493-513

Clarkson, B.D. 1990: A review of vegetation development following recent (<450 years) volcanic disturbance in North Island, New Zealand. *New Zealand journal of ecology*. 14:59-71

Clarkson, B.D. 1991: Heart-leaved kohuhu (*Pittosporum obcordatum*) rediscovered near Kaitaia. *Newsletter / New Zealand Botanical Society*. 26:10-12

Clarkson, B.D. 1992: [Book review]: *A manual of the flowering plants of Hawaii*, by Warren L. Wagner, Derral R. Herbst, and S.H. Sohmer. *New Zealand journal of botany*. 30(1):119-120

Clarkson, B.D.; Clarkson, B.R. 1991: A century of change on Mt Tarawera. *In*: Clarkson, B.D.; Smale, M.C.; Ecroyd, C.E. Botany of Rotorua. Forest Research Institute, Rotorua. p. 79-84

Clarkson, B.D.; Nicholls, J.L. 1992: The distribution of beech (*Nothofagus*) species in the east Taupo zone after the 1850 BP volcanic eruptions. *Newsletter / Rotorua Botanical Society*. 25:15-33

Clarkson, B.D.; Smale, M.C.; Ecroyd, C.E. (comps.) 1991: Botany of Rotorua. [2], vi, 132 p. Forest Research Institute, Rotorua.

Clarkson, B.R.; Clarkson, B.D. 1991: Mires. *In*: Clarkson, B.D.; Smale, M.C.; Ecroyd, C.E. Botany of Rotorua. Forest Research Institute, Rotorua. p. 59-64

Clarkson, B.R.; Clarkson, B.D. 1991: Turanga Ecological District: survey report for the Protected Natural Areas Programme. New Zealand Protected Natural Areas Programme; 14. 131 p. Department of Conservation, Gisborne.

Clarkson, B.R.; Clarkson, B.D.; Patel, R.N. 1992: The pre-Taupo eruption (*c.* AD 130) forest of the Benneydale-Pureora district, central North Island, New Zealand. *Journal of the Royal Society of New Zealand*. 22(2):61-76

Clayden, B. 1990: In memoriam: Dr. M.L. Leamy (1930-1990). *Bulletin of the International Society of Soil Science*. 77:35-36

Clayden, B.; Daly, B.K.; Lee, R.; Mew, G. 1990: The nature, occurrence, and genesis of placic horizons. *In*: Kimble, J.M.; Yeck, R.D. (*eds*). Proceedings of the Fifth International Soil Correlation Meeting (ISCOM): characterization, classification, and utilisation of spodosols. USDA, Soil Conservation Service, National Soil Survey Centre, Lincoln, NE. p. 88-104

Clayden, B.; Hewitt, A.E. 1990: Why another system of horizon notation. *New Zealand soil news*. 38:18-21

Clayden, B.; Hewitt, A.E.; Lee, R.; Watt, J.P.C. 1992: The properties of pseudogleys in New Zealand loess. *In*: Kimble, J.M. (*ed.*). Proceedings of the Eighth International Soil Correlation Meeting (VIII ISCOM): characterization, classification, and utilisation of wet soils. USDA, Soil Conservation Service, National Soil Survey Centre, Lincoln, NE. p. 60-65

Claydon, J.J.; Muneyoshi, A.; Childs, C.W.; Yoshinaga, N. 1992: "Ultimate" (primary particle) size fractionation of soil samples from New Zealand and the South Pacific. DSIR Land Resources scientific report; 33. 23 p. DSIR Land Resources, Lower Hutt.

Clements, M.A.; Jones, D.L.; Molloy, B.P.J. 1991: Recently named Australian orchid taxa. 2, *Thelymitra*. *Lindleyana*. 6(1):59-60

Clout, M.N.; Karl, B.J.; Gaze, P.D. 1991: Seasonal movements of New Zealand pigeons from a lowland forest reserve. *Notornis*. 38:37-47

Clout, M.N.; Tilley, J.A.V. 1992: Germination of miro (*Prumnopitys ferruginea*) seeds after consumption by New Zealand pigeons (*Hemiphaga novaeseelandiae*). *New Zealand journal of botany*. 30(1):25-28

Connor, H.E. 1990: *Elymus* (Gramineae) on Norfolk Island. *Kew bulletin*. 45(4):680

Connor, H.E. 1991: *Chionochloa* Zotov (Gramineae) in New Zealand. *New Zealand journal of botany*. 29(3):219-282

Connor, H.E. 1991: [Letter to the editor]: *Poisonous plants in New Zealand* by Jose Steuart, revised edition 1989, GP Books (Wellington). *New Zealand journal of botany*. 29(1):95

Connor, H.E.; Jacobs, S.W.L. 1991: Sex ratios in dioecious Australian grasses: a preliminary assessment. *Cunninghamia*. 2(3):385-390

Cook, F.J. 1990: What does an auger hole measure? *Wispas*. July 1990:[5]

Cook, F.J. 1991: Calculation of hydraulic conductivity from suction permeameter measurements. *Soil science*. 152(5):321-325

Cook, F.J.; Barton, P. 1990: Soil physics and hydrology. *Wispas*. July 1990:[5]

Cooke, J.G.; Cooper, A.B.; Clunie, N.M.U. 1991: Changes in the water, soil, and vegetation of a wetland after a decade of receiving a sewage effluent. *New Zealand journal of ecology*. 14:37-47

Cowan, H.A.; McGlone, M.S. 1991: Late Holocene displacements and characteristic earthquakes on the Hope River segment of the Hope Fault, New Zealand. *Journal of the Royal Society of New Zealand*. 21(4):373-384

Cowan, P.E. 1990: Brushtail possum. *In*: King, C.M. (*ed.*). The handbook of New Zealand mammals. Oxford University Press, Auckland. p. 67-98

Cowan, P.E. 1990: Fruits, seeds and flowers in the diet of brushtail possums, *Trichosurus vulpecula*, in lowland podocarp/mixed hardwood forest, Orongorongo Valley, New Zealand. *New Zealand journal of zoology*. 17:549-566

Cowan, P.E. 1990: Forest ecology in the Orongorongo Valley. *Five miler*. 111:2-8

Cowan, P.E. 1991: The ecological effects of possums on the New Zealand environment. Publication / Veterinary Continuing Education, Massey University. 132:73-88

Cowan, P.E. 1991: Effects of introduced Australian brushtail possums (*Trichosurus vulpecula*) on the fruiting of the endemic New Zealand nikau palm (*Rhopalostylis sapida*). *New Zealand journal of botany*. 29(1):91-93

Cowan, P.E. 1992: Possums - their introduction and spread. Ecology notes; 26. 2 p. DSIR Land Resources, Lower Hutt.

Cowan, P.E. 1992: Possums and Tb. Ecology notes; 27. 2 p. DSIR Land Resources, Lower Hutt.

Cowan, P.E.; Blackmore, D.K.; Marshall, R.B. 1991: Leptospiral infection in common brushtail possums (*Trichosurus vulpecula*) from lowland podocarp/mixed hardwood forest in New Zealand. *Wildlife research*. 18:719-727

Cowan, P.E.; Rhodes, D.S. 1992: Restricting the movements of brushtail possums (*Trichosurus vulpecula*) on farmland with electric fencing. *Wildlife research*. 19:47-58

Cowan, P.E.; Waddington, D.C. 1990: Suppression of fruit production of the endemic forest tree, *Elaeocarpus dentatus*, by introduced marsupial brushtail possums, *Trichosurus vulpecula*. *New Zealand journal of botany*. 28(3):217-224.

Cowan, P.E.; Waddington, D.C. 1991: Litterfall under hinau, *Elaeocarpus dentatus*, in lowland podocarp/mixed hardwood forest, and the impact of brushtail possums, *Trichosurus vulpecula*. *New Zealand journal of botany*. 29(4):385-394

Cowie, J.D.; Searle, P.L.; Widdowson, J.P.; Orbell, G.E. 1991: Soils of Tongatapu, Kingdom of Tonga. DSIR Land Resources scientific report; 21. 55 p. DSIR Land Resources, Lower Hutt.

Cree, A.; Cockrem, J.F.; Guillette, L.J. 1992: Reproductive cycles of male and female tuatara (*Sphenodon punctatus*) on Stephens Island, New Zealand. *Journal of zoology*. 226:199-217

Cree, A.; Guillette, Jr., L.J.; Cockrem, J.F. 1991: Identification of female tuatara in ovulatory condition using plasma sex steroid concentrations. *New Zealand journal of zoology*. 18(4):421-426

Daugherty, C.H.; Towns, D.R.; Atkinson, I.A.E.; Gibbs, G.W. 1990: The significance of the biological resources of New Zealand islands for ecological restoration. *In*: Towns, D.R.; Daugherty, C.H.; Atkinson, I.A.E. Ecological restoration of New Zealand islands. (Conservation sciences publication; 2). Department of Conservation, Wellington. p. 9-21

Daniel, M.J. 1991: Native bats. Ecology notes; 9. 2 p. DSIR Land Resources, Lower Hutt.

Dawson, M.I. 1990: *Leptospermum scoparium* (manuka): chromosome variation of cultivars. *Horticulture in New Zealand*. 1(2):15-19

DeRose, R.C.; Trustrum, N.A.; Blaschke, P.M. 1991: Geomorphic change implied by regolith-slope relationships on steepland hillslopes, Taranaki, New Zealand. *Catena*. 18:489-514

DeRose, R.C.; Trustrum, N.A.; Blaschke, P.M. 1992: Quantification of post-deforestation soil loss from steepland hillslopes in Taranaki, New Zealand. Earth Surface Processes and Landforms, 1st Revision.

de Wit, N.M.M.; McQueen, D.J. 1992: Compactibility of materials for land rehabilitation. DSIR Land Resources scientific report; 7. 69 p. DSIR Land Resources, Lower Hutt.

Decourtye, L.; Harris, W.; Cadic, A. 1991: Collecte et evaluation d'arbustes ornementaux spontanes en Nouvelle-Zelande et au Nepal (Collection and evaluation of spontaneous ornamental shrubs from New Zealand and Nepal). *Comptes rendus des seances de l'Academie d'Agriculture de France*. 77(1):75-88

Dickinson, K.J.M.; Mark, A.F.; Lee, W.G. 1992: Long-term monitoring of non-forest communities for biological conservation. *New Zealand journal of botany*. 30:163-179

Dymond, J.R. 1991: An improved spectral classifier.

In: Proceedings of the 6th New Zealand Image Processing Workshop, August 29-30 1991, Lower Hutt. DSIR Physical Sciences, Information Technology Group, Lower Hutt. p. 47-52

Dymond, J.R. 1992: Nonparametric modelling of radiance in hill country for digital classification of aerial photographs. *Remote sensing of the environment*. 39:95-102

Dymond, J.R.; DeRose, R.C.; Trotter, C.M. 1992: DTMs for terrain evaluation. *Geocarto international*. 7(2):1-6

Dymond, J.R.; Stephens, P.R.; Newsome, P.F.; Wilde, R.H. 1991: Mapping percentage vegetation cover using SPOT satellite data. *In*: Murai, S. Asian Association on Remote Sensing, Applications of remote sensing in Asia and Oceania - environmental change monitoring. Asian Association on Remote Sensing, Tokyo. p. 112-113

Ecroyd, C.E.; Clarkson, B.D.; Wilcox, M. 1990: Annotated list of vascular plants in the Rotorua Lakes Ecological District. Special issue / Rotorua Botanical Society; 1. [i], 69 p. Rotorua Botanical Society, Rotorua.

Eden, D.N. 1992: A standard method for determining volcanic glass content in Andisols. DSIR Land Resources scientific report; 2. 27 p. DSIR Land Resources, Lower Hutt.

Edgar, E.; Connor, H.E.; Shand, J.E. 1991: Checklist of oryzoid, arundinoid, and chloridoid grasses naturalised in New Zealand. *New Zealand journal of botany*. 29(2):117-129

Edgar, E.; Forde, M.B. 1991: *Agrostis* L. in New Zealand. *New Zealand journal of botany*. 29(2):139-161

Edgar, E.; O'Brien, M.-A.; Connor, H.E. 1991: Checklist of pooid grasses naturalised in New Zealand. 1, Tribes Nardeae, Stipeae, Hainardieae, Meliceae, and Aveneae. *New Zealand journal of botany*. 29(2):101-116

Efford, M.G. 1991: The ecology of an uninfected forest possum population. Symposium on tuberculosis. Publication / Veterinary Continuing Education. 132:41–51

Efford, M.G. 1991: A review of possum dispersal. DSIR Land Resources scientific report; 23. 70p. DSIR Land Resources, Lower Hutt.

Efford, M.G.; Morrison, K. 1991: Counts of forest birds in the Hollyford and Eglinton Valleys, Fiordland: the possible effects of stoat trapping. DSIR Land Resources scientific report; 20. 43 p. DSIR Land Resources, Lower Hutt.

Esler, A.E. 1991: Changes in the native plant cover of urban Auckland, New Zealand. *New Zealand journal of botany*. 29(2):177-196

Espie, P.R.; Connor, H.E.; McCracken, I.J. 1992: Leaf-blade crimping in grasses: a new measure of growth. *Experientia*. 48:91-94

Eyles, G.O.; Newsome, P.F. 1990: A decade of experience using a New Zealand geographic information system. *New Zealand geographer*. 46 (1):43-47

Eyles, G.O.; Trustrum, N.A. 1992: Physical resource issues leading towards sustainable agriculture. *In*: Sims, R.E.H. (*ed.*). Proceedings of a workshop on moving towards sustainable agriculture. July 31-August 1, 1991. Massey University, Palmerston North. p. 1-10

Fife, A.J. 1990: *Brachythecium fontanum* (Musci, Brachytheciaceae), a new species from the South Island of New Zealand. *New Zealand journal of botany*. 28(2):125-130

Fife, A.J. 1992: *Beeveria* (Hookeriaceae), a new genus from New Zealand. *Contributions from the University of Michigan Herbarium*. 18:141-147

Fife, A.J.; Shaw, A.J. 1990: *Epipterygium* (Musci: Bryaceae) new to Australasia, with the description of *E. opararense*, sp. nov. *New Zealand journal of botany*. 28(4):375-379

Fitzgerald, B.M.; Karl, B.J.; Veitch, C.R. 1991: The diet of feral cats (*Felis catus*) on Raoul Island, Kermadec Group. *New Zealand journal of ecology*. 15(2):123-129

Fletcher, J.R. 1990: Land resource survey of the Wiroko Subwatershed, Upper Solo Watershed, Central Java, Indonesia. DSIR Land Resources scientific report; 12. 157 p. DSIR Land Resources, Lower Hutt.

Fletcher, J.R.; Gibb, R.G. 1990: Land resource survey handbook for soil conservation planning in Indonesia. DSIR Land Resources scientific report; 11. 127 p. DSIR Land Resources, Lower Hutt.

Flux, J.E.C. 1990: Brown hare. *In*: King, C.M. (*ed.*). The handbook of New Zealand mammals. Oxford University Press, Auckland. p. 161-172

Flux, J.E.C. 1990: Impact impression of New Zealand pigeon on window. *Notornis*. 37:120

Flux, J. 1991: What's wrong with using myxomatosis? *Mammal news*. 87:6

Flux, J.E.C. 1991: Deems'e vole love's meed? Hares are level, eraser, ah? *Evolutionary ecology*. 5:428-429

Flux, J.E.C.; Brockie, R.E. 1991: The cat's lunch. *New Zealand science monthly*. 2(5):14-15

Forsyth, J.; Turnbull, I.M.; Lee, B.; Beecroft, G. 1991: A guide to the Kepler Track. 47 p. John McIndoe, Dunedin.

Franks, A.M.; Neall, V.E.; Pollok, J.A. 1991: Soils of part Eltham County, North Island, New Zealand. DSIR Land Resources scientific report; 14. 131 p. DSIR Land Resources, Lower Hutt.

Galloway, D.J. 1992: Checklist of New Zealand lichens; edited by A.J. Fife. DSIR Land Resources scientific report; 26. 58 p. DSIR Land Resources, Christchurch.

Garnock-Jones, P.J. 1990: Typification of *Ranunculus* names in New Zealand (Ranunculaceae). *New Zealand journal of botany*. 28(2):115-123

Garnock-Jones, P.J. 1991: Seed morphology and anatomy of the New Zealand genera *Cheesemania*,

Ischnocarpus, *Iti*, *Notothlaspi*, and *Pachycladon* (Brassicaceae). *New Zealand journal of botany*. 29(1):71-82

Garnock-Jones, P.J. 1991: Gender dimorphism in *Cheesemania wallii* (Brassicaceae). *New Zealand journal of botany*. 29(1):87-90

Garnock-Jones, P.J. 1991: Hebes in the wild. *In*: The native plants of New Zealand: a selection of papers from the symposium on NZ native plants, Bay of Plenty Polytech, August 1-2, 1990. Reference Publishing Co., Auckland. p. 59-67

Garnock-Jones, P.J. 1991: Why do plant names change? *Bulletin / New Zealand Rhododendron Association*. 79:49-53

Garnock-Jones, P.J. 1991: Collecting plants in New Zealand - legal and conservation issues. *Hebe news*. 6(3):23-24

Garnock-Jones, P.J. 1991: Plants in isolation. *In*: Moore, D.M. (*ed.*). Plant life. Oxford University Press, New York. p. 238-245

Garnock-Jones, P.J.; Briggs, B.G.; Ehrendorfer, F. 1990: Proposal to conserve 7579a *Parahebe* W. Oliver against *Derwentia* Raf. (Scrophulariaceae). *Taxon*. 39(3):536-537

Garnock-Jones, P.J.; Scholes, P. 1990: Alkaloid content of *Papaver somniferum* subsp. *setigerum* from New Zealand. *New Zealand journal of botany*. 28(3):367-369

Gibb, R.G. 1990: DSIR ARC/Manager user's guide for Indonesian Ministry of Forestry. DSIR Land Resources scientific report; 13. 66 p. DSIR Land Resources, Lower Hutt.

Giddens, K.M.; Searle, P.L. 1991: Soil chemistry. *In*: Mew, G; Ross, C.W. Soils, agriculture and forestry of the Westport region, West Coast, South Island, New Zealand. DSIR Land Resources scientific report; 1. DSIR Land Resources, Lower Hutt. p. 40-48

Gitay, H.; Wilson, J.B.; Lee, W.G.; Allen, R.B. 1991: *Chionochloa rigida* tussocks thirteen years after spring and autumn fire, Flagstaff, New Zealand. *New Zealand journal of botany*. 29(4):459-462

Given, D.R. 1990: Botany and fauna. *In*: Wairakei Geothermal Power Station water application and impact assessment, Taupo. Electricorp Production. p. 219-231

Given, D.R. 1990: Discovery of a conservation ethic: a challenge for the 1990s. *Directions*. 5:1-3

Given, D.R. 1991: Rare and endangered species. *In*: The native plants of New Zealand: a selection of papers from the symposium on NZ native plants, Bay of Plenty Polytech, August 1-2, 1990. Reference Publishing Co., Auckland. p. 78-87

Given, D.R. 1991: Conservation: plants for people and people for plants. *Bulletin / Dunedin Rhododendron Group*. 18:43-48

Given, D.R. 1991: Tending the garden - rediscovering stewardship of creation. *Reaper*. 73(1):3-5

Given, D.R. 1991: [Book review]: *Green Christianity*, by Tim Cooper (Spire, 1990), 282 p. *Tending the garden*, edited by Wesley Granberg-Michaelson (Eerdmans, 1987) 150 p. *Latimer journal*. 109:60-62

Given, D.R. 1992: Priorities for plant conservation in New Zealand. *In*: Butler, G.; Meredith, L.; Richardson, M. (*eds*). Conservation of rare or threatened plants in Australasia. Proceedings of the conference protective custody: *ex situ* plant conservation in Australasia. Australian National Parks and Wildlife Service, Canberra. p. 19-30

Godley, E.J. 1991: Biographical notes (1): John William Hall (1830-1915). *Newsletter / New Zealand Botanical Society*. 23:17

Godley, E.J. 1991: Biographical notes (2): Albert James Allom (1825-1909). *Newsletter / New Zealand Botanical Society*. 24:11-12

Godley, E.J. 1991: Biographical notes (3): Henry John Matthews (1859-1909) and Grace Annie Matthews (c. 1874-1967). *Newsletter / New Zealand Botanical Society*. 25:11-13

Godley, E.J. 1991: Biographical notes (4): Joseph Hobson McMahon (c. 1874-1948). *Newsletter / New Zealand Botanical Society*. 26:13-15

Godley, E.J. 1991: Biographical notes (5): Frederick Hamilton Spencer (1854-1932). *Newsletter / New Zealand Botanical Society*. 27:17-18

Godley, E.J. 1991: Biographical notes (6): Peter Goyden (1845-1927). *Newsletter / New Zealand Botanical Society*. 28:15-16

Greer, D.H.; Muir, L.A.; Harris, W. 1991: Seasonal frost hardiness in *Leptospermum scoparium* seedlings from diverse sites throughout New Zealand. *New Zealand journal of botany*. 29(2):207-212

Gregory, G.; McGlone, M. 1991: Climate change and New Zealand: what the past tells us about the future. Alpha: DSIR extension information; 78. 5 p. DSIR Publishing, Wellington.

Griffiths, E.; Horner, I. 1991: Soil management and irrigation for *Phytophthora* control. Technical bulletin / New Zealand Apple and Pear Marketing Board. Dec:3-16

Grigor, M.R.; Bennett, B.L.; Carne, A.; Cowan, P.E. 1991: Whey proteins of the common brushtail possum (*Trichosurus vulpecula*): isolation, characterization and changes in concentration in milk during lactation of transferrin, alpha-lactalbumin and serum albumin. *Comparative biochemistry and physiology*. 98B:451-459

Harmsworth, G.R. 1990: Appendix V: the NZLRI - computerised physical resource database. *In*: Adcock, H.M.; McEwen, W.M. Report on the Department of Conservation's National Database Workshop. (Science and research internal report; 88). Department of Conservation, Wellington. p. 59-64

Harmsworth, G.R. 1992: New Zealand Land Resource Inventory worksheet (second edition). 26 sheets of the Northland area based on DOSLI Info Map 260 series. (Scale 1:50 000). DSIR Land Resources, Aokautere.

Harmsworth, G.R.; Page, M.J. 1991: A review of selected storm damage assessments in New Zealand. DSIR Land Resources scientific report; 9. 34 p. DSIR Land Resources, Lower Hutt.

Harris, R.J.; Moller, H.; Tilley, J.A.V. 1991: Weather-related differences in attractiveness of protein foods to *Vespula* wasps. *New Zealand journal of ecology*. 15(2):167-170

Harris, W. 1990: Nerine collection. *New Zealand gardener*. 46(10):5

Harris, W. 1990: Clematis. *Commercial horticulture*. December 1990:28-29

Harris, W. 1990: D'Urville: explorer worthy of higher history slot. *The Press* (Christchurch). 18 May 1990:11

Harris, W. 1990: Spectacular Weigelas released in Europe. *Commercial horticulture*. May 1990:12-13

Harris, W. 1991: Native plants: the scientific viewpoint. *In*: The native plants of New Zealand: a selection of papers from the symposium on NZ native plants, Bay of Plenty Polytech, August 1-2, 1990. Reference Publishing Co., Auckland. p. 47-58

Harris, W. 1991: Choice of site critical to new Amberley nursery. *Commercial horticulture*. April 1991:26–28

Harris, W.; Decourtye, L. 1991: The potential for New Zealand native plants in Europe. *In*: The native plants of New Zealand : a selection of papers from the symposium on NZ native plants, Bay of Plenty Polytech, August 1–2, 1990. Reference Publishing Co., Auckland. p.18–40

Harris, W.; Decourtye, L. 1991: Winter climatic comparison between France and New Zealand : effects of frost damage on populations of *Leptospermum scoparium* JR et G Forst grown at three locations in France. *Agronomie*. 11:847–861

Harris, W.; Heenan, P.B. 1991: *Cordyline* 'ti tawhiti' and its relationship to *Cordyline* 'Thomas Kirk'. *Horticulture in New Zealand*. 2(2):2–5

Harris, W.; Heenan, P.B. 1991: Whence "ti tawhiti"? *Newsletter / New Zealand Botanical Society*. 25:7–8

Heenan, P.B. 1991: Checklist of *Phormium* cultivars. 60 p. Royal New Zealand Institute of Horticulture, Lincoln.

Heenan, P.B. 1991: *Cordyline* cultivar names : three new combinations. *Horticulture in New Zealand*. 2(1):6–7

Heenan, P.B. 1991: A cultivar checklist for the New Zealand species of *Cordyline* (Asphodelaceae). *Horticulture in New Zealand*. 2(1):8–12

Heenan, P.B. 1991: *Olearia* x *matthewsii* 'Highland Mist' : a new interspecific and cultivar name. *Horticulture in New Zealand*. 2(2):13–14

Heenan, P.B. 1992: The origin of *Sophora* 'Gnome' and the growth habit of *Sophora* 'Earlygold'. *Horticulture in New Zealand*. 3(1):2–6

Heenan, P.B.; Harris, W. 1992: Maori crop plant grown today. *New Zealand gardener*. 48(1):48–49

Hewitt, A.E. 1990: Soil classification. *New Zealand commercial grower*. 45(3):27, 39

Hewitt, A.E. 1990: A new soil classification for New Zealand. *In*: Transactions, 14th International Congress of Soil Science, Kyoto, Japan, August 1990, Volume V : Commission V. 540p. International Society of Soil Science, Kyoto, Japan. p. 22–27

Hewitt, A.E. 1991: New Zealand soil classification : extracts [in Chinese]. [*Progress in soil science*.] 19(4):55–61

Hewitt, A.E. 1992: New Zealand soil classification. DSIR Land Resources scientific report ; 19. 131 p. DSIR Land Resources, Lower Hutt.

Hewitt, A.E.; Beecroft, F.G. 1991: Aridisols of New Zealand. *In*: Proceedings of the Sixth International Correlation Meeting, (VI ISCOM) : characterisation, classification and utilisation of cold aridisols and vertisols. Soil Conservation Service, USDA; Washington, D.C. p. 67–72

Hicks, D.L. 1990: Small watercourses in Otago and Southland: geomorphology, hydrology, some effects on land and water use. *In*: Kearsley, G.; Fitzharris, B. (*eds*). Southern landscapes : essays in honour of Bill Brockie and Ray Hargreaves. University of Otago, Dunedin. p. 199–212

Hicks, D.L. 1991: Storm on a hill. *Terra Nova*. 4:51-52

Hicks, D.L. 1991: Erosion under pasture, pine plantations, scrub and indigenous forest : a comparison from Cyclone Bola. *New Zealand forestry*. 36 (3):21–22

Hicks, D.L.; Omura, H. 1992: Probability of landslides in hill country. *In*: Bell, D.H. (*ed*). Landslides. Proceedings of the Sixth International Symposium, 10–14 February 1992, Christchurch. Balkema, Rotterdam. p. 1045–1049

Horne, D.J.; Ross, C.W.; Hughes, K.A. 1992: Ten years of a maize / oats rotation under three tillage systems on a silt loam in New Zealand. 1. A comparison of some soil properties. *Soil and tillage research*. 22:131–143

Hughes, K.A.; Horne, D.J.; Ross, C.W.; Julian, J.F. 1992: A 10–year maize / oats rotation under three tillage systems. 2. Plant population, root distribution and forage yields. *Soil and tillage research*. 22:145–157

Hughes, K.A.; Shepherd, T.G.; Wilde, R.H. 1992: Soil structure and drainage : a balancing act between successful orcharding and bankruptcy. *In*: Horne, D.J.; Furkert, I.F.H. (*eds*). Proceedings of the Fifth National Land Drainage Seminar held at Massey University, Palmerston North, New Zealand, 16–17 August 1990. p. 1–7

Hunter, G.G. 1991: The distribution of hawkweeds (*Hieracium* spp.) in the South Island, indicating problem status. *Review : journal of the New Zealand Mountain Lands Institute*. 48:21–31

Johnson, P.N. 1990: Gumboot gardens. *New Zealand gardener*. 46(11):38–39

Johnson, P.N. 1991: Hedge me in. *New Zealand gardener*. 47(4):32–33

Johnson, P.N. 1991: A garden in the land of glowing skies. *New Zealand gardener*. 47(4):56–57

Johnson, P.N. 1991: A garden island halfway across the Tasman. *New Zealand gardener*. 47(6):56–57

Johnson, P.N. 1992: Going on a dig. *New Zealand gardener*. 48(1):54–55

Johnson, P.N. 1992: The sand dune and beach vegetation inventory of New Zealand. II, South Island and Stewart Island. DSIR Land Resources scientific report ; 16. 278 p. DSIR Land Resources, Christchurch.

Johnson, P.N. 1992: Gardens in Fiji. *New Zealand gardener*. 48(7):52–55

Laffan, M.D.; Vincent, K. W. 1990: Soils of the Blenheim-Renwick District. *In*: Rae, S.N.; Tozer, G. (*eds*). Water and soil resources of the Wairau. Volume three, land and soil resources. Nelson-Marlborough Regional Council, Blenheim, p.75–102

Langham, N.P.E. 1990: The diet of feral cats (*Felis catus* L.) on Hawke's Bay farmland, New Zealand. *New Zealand journal of zoology*. 17(2):243–255

Langham, N.P.E.; Charleston, W.A.G. 1990: An investigation of the potential for spread of *Sarcocystis* spp. and other parasites by feral cats. *New Zealand journal of agricultural research*. 33(3):429–435

Langham, N.P.E.; Porter, R.E.R. 1991: Feral cats (*Felis catus* L.) on New Zealand farmland. I, Home range. *Wildlife research*. 18:741–760

Langham, N.P.E.; Porter, R.E.R. 1991: The effect of poisoning on the movement of rooks *Corvus frugilegus* L. in southern Hawke's Bay, New Zealand. *New Zealand journal of zoology*. 18(4):389–398

Leamy, M.L.; Kinloch, D.I.; Parfitt, R.L. 1990: International Committee on Andisols : final report. Technical monograph / United States, Soil Management Support Services ; 20. v, 164 p. Soil Management Support Services; Washington, D.C.

Lee, R.; Cornforth, I.S.; Edmeades, D.C.; Watkinson, J.H. 1991: A comparative study of MAF (Ruakura) and DSIR Land Resources soil analysis results. *New Zealand journal of agricultural research*. 34(2):227–233

Lee, W.G. 1992: New Zealand ultramafics. *In*: Roberts, B.A.; Proctor, J. The ecology of areas with serpentinized rocks : a world view. Kluwer, Dordrecht. p. 375–418

Lee, W.G.; Clout, M.N.; Robertson, H.A.; Wilson, J.B. 1991: Avian dispersers and fleshy fruits in New Zealand. *In*: Acta XX Congressus Internationalis Ornithologici, Christchurch, New Zealand, 2–9 December 1990. 4 v. (2568 p.) + 1 supplement. New Zealand Ornithological Congress Trust Board, Wellington. p. 1617–1623

Lee, W.G.; Grubb, P.J.; Wilson, J.B. 1991: Patterns of resource allocation in fleshy fruits of nine European tall shrub species. *Oikos*. 61:307–315

Lee, W.G.; Hodgkinson, I.J.; Johnson, P.N. 1990: A test for ultraviolet reflectance from fleshy fruits of New Zealand plant species. *New Zealand journal of botany*. 28:21–24

Lee, W.G.; Littlejohn, R.P.; Prema, P.G. 1991: Growth of *Pinus radiata* in relation to foliar element concentrations on ultramafic soil, New Zealand. *New Zealand journal of botany*. 29(2):163–167

Lee, W.G.; Ward, C.M.; Wilson, J.B. 1991: Comparison of altitudinal sequences of vegetation on granite and metasedimentary rocks in the Preservation Ecological District, southern Fiordland, New Zealand. *Journal of the Royal Society of New Zealand*. 21(3):261–276

Lee, W.G.; Wilson, J.B.; Meurk, C.D.; Kennedy, P.C. 1991: Invasion of the subantarctic Auckland Islands, New Zealand, by the asterad tree *Olearia lyallii* and its interaction with a resident myrtaceous tree *Metrosideros umbellata*. *Journal of biogeography*. 18:493–508

Lloyd, D.G.; Webb, C.J.; Dulberger, R. 1990: Heterostyly in species of *Narcissus* (Amaryllidaceae) and *Hugonia* (Linaceae) and other disputed cases. *Plant systematics and evolution*. 172(1/4):215–227

Lloyd, D.G.; Webb, C.J. 1992: The evolution of heterostyly. *In*: Barrett, S.C.H. Evolution and function of heterostyly. 1 v. (Monographs on theoretical and applied genetics ; 15). Springer, Berlin. p. 151–178

Lloyd, D.G.; Webb, C.J. 1992: The selection of heterostyly. *In*: Barrett, S.C.H. Evolution and function of heterostyly. 1 v. (Monographs on theoretical and applied genetics ; 15). Springer, Berlin. p. 179–207

Luckman, P.G. 1991: Erosion control in the Manawatu-Wanganui region. *In*: Forum on Sustainable Resource Management. [Manawatu-Wanganui Regional Council, Palmerston North]. p. 109–123

Luckman, P.G.; Jessen, M.R.; Gibb, R.G. 1990: Use of expert systems and GIS in land evaluation. *New Zealand geographer*. 46(1):15–20

Lynn, I.H.; Crippen, T.F. 1991: Rock type classification for the New Zealand Land Resource Inventory. DSIR Land Resources scientific report ; 10. 123 p. DSIR Land Resources, Lower Hutt.

Macmillan, B.H. 1991: *Acaena pallida* (Kirk) Allan (Rosaceae) in Tasmania and New South Wales, Australia. *In*: Banks, M.R.; Smith, S.J.; Orchard, A.E.; Kantvilas, G. Aspects of Tasmanian botany : a tribute to Winifred Curtis. [vi], 247 p. Royal Society of Tasmania, Hobart, Tasmania. p. 53–55

Macmillian, B.H. 1991: *Acaena rorida* and *Acaena tesca* (Rosaceae) - two new species from New Zealand. *New Zealand journal of botany*. 29(2):131–138

Malham, J.P.; Rees, J.S.; Alspach, P.A.; Beggs, J.R.; Moller, H. 1991: Traffic rate as an index of colony

size in *Vespula wasps*. *New Zealand journal of zoology*. 18(2):105–109

Markham, K.R.; Franke, A.; Given, D.R.; Brownsey, P. 1990: Historical Antarctic ozone level trends from herbarium specimen flavonoids. *Bulletin de liaison du Groupe polyphenols*. 15:232–235

Mather, L.J.; Williams, P.A. 1990: Phenology, seed ecology, and age structure of Spanish heath (*Erica lusitanica*) in Canterbury, New Zealand. *New Zealand journal of botany*. 28(3):207–215

McDonald, W.S.; Smith, S.M. 1991: An integrated national land resource coverage : New Zealand experiences. *In*: Heit, M.; Shortreid, A. GIS Applications in Natural Resources. GIS World; Fort Collins, Colorado. p. 245–250

McGlone, M.S. 1990: Global change and ecological complexity. Global change in New Zealand. Proceedings of the Royal Society of New Zealand Conference, 14–15 June 1990, Science House, Wellington. (Bulletin / Royal Society of New Zealand ; 29). p. 56–62

McGlone, M.S. 1991: Late Pleistocene and Holocene vegetation and landscape studies in New Zealand. *In*: McFadgen, B.; Simpson, P. (*eds*). Research directions for conservation science? (Science and research series ; 37). Department of Conservation, Wellington. p. 1–16

McGlone, M.S.; Clarkson, T.; Fitzharris, B. 1990: Unsettled-outlook : New Zealand and the greenhouse effect. 128 p..GP Books, Wellington.

McIntosh, P.D. 1991: Southern soils : soils for horticulture in Otago and Southland. *Growing today*. July 1991:21

McIntosh, P.D. 1992: Soils of the Kaiwera district, eastern Southland, New Zealand. DSIR Land Resources scientific report ; 32. 105 p. DSIR Land Resources, Dunedin.

McIntosh, P.D. 1992: Soil map of Mandeville district, South Island, New Zealand (2 sheets. scale 1:25000). DSIR Land Resources map ; 317.

McIntosh, P.D.; Allan, B.E.; Dreaver, K.R. 1992: Soils and land use potential on Tara Hills High Country Research Station, Omarama. DSIR Land Resources scientific report ; 24. 80 p. DSIR Land Resources, Dunedin.

McIntosh, P.D.; Allen, R.B. 1992: Narcissi bulb production at southern South Island sites, New Zealand. *New Zealand journal of crop and horticultural science*. 20:17–21

McIntosh, P.D.; Allen, R.B.; Porter, N.G.; Lammerink, J.F. 1992: Garlic production in North Otago and Southland, New Zealand. *New Zealand journal of crop and horticultural science*. 20:11–16

McIntosh, P.D.; Eden, D.N.; Burgham, S.J. 1990: Quaternary deposits and landscape evolution in northeast Southland, New Zealand. *Palaeogeography, palaeoclimatology, palaeoecology*. 81:95–113

McIntosh, P.D.; Kemp, R.A. 1991: Consolidated horizons in soils formed in aeolian deposits in Southland, New Zealand. *Geoderma*. 50:109–124

McLennan, J. 1990: New Zealand's kiwis. *New Zealand science teacher*. 64:26–28

McLennan, J.A. 1990: Brown kiwis. *In*: Fuller, E. Kiwis : a monograph of the family Apterygidae. 187 p. Seto Publishing, Auckland. p. 37–58

McLennan, J.A. 1990: The South Island brown kiwi, *Apteryx australis australis*. *In*: Fuller, E. Kiwis : a monograph of the family Apterygidae. 187 p. Seto Publishing, Auckland. p. 59–64

McLennan, J.A. 1990: The Stewart Island brown kiwi, *Apteryx australis lawryi*. *In*: Fuller, E. Kiwis : a monograph of the family Apterygidae. 187 p. Seto Publishing, Auckland. p. 65–68

McLennan, J.A. 1990: The North Island brown kiwi, *Apteryx australis mantelli*. *In*: Fuller, E. Kiwis: a monograph of the family Apterygidae. 187 p. Seto Publishing, Auckland. p. 69-71

McLennan, J.A. 1990: The great spotted kiwi, *Apteryx haastii*. *In*: Fuller, E. Kiwis: a monograph of the family Apterygidae. 187 p. Seto Publishing, Auckland. p. 72-85

McLennan, J.A.; McCann, A.J. 1991: Incubation temperatures of great spotted kiwi, *Apteryx haastii*. *New Zealand journal of ecology*. 15(2):163-166

McLeod, M. 1992: Soils of the proposed Te Kawa Irrigation Area, North Island, New Zealand. DSIR Land Resources scientific report; 25. 33 p. DSIR Land Resources, Lower Hutt.

McLeod, M. 1992: Soils of the Hauraki Plains County, North Island, New Zealand. DSIR Land Resources scientific report; 31. 162 p. DSIR Land Resources, Lower Hutt.

McLeod, M. 1992: Soils of Dobuilevu Agricultural Research Station, Viti Levu, Fiji. New Zealand soil survey report; 84. 43 p. 1 map.

McLeod, M. 1992: Soils of part northern Matamata County, North Island, New Zealand. DSIR Land Resources scientific report; 18. DSIR Land Resources, Lower Hutt.

McLeod, M. 1992: Soil map of Hauraki Plains County, North Island, New Zealand. Scale 1:50 000. DSIR Land Resources map; 312.

McLeod, M.; Kennedy, N.M. 1990: Soil map of part northern Matamata County. Scale 1:50 000. DSIR Land Resources map; 310.

McLeod, M.; Singleton, P.L. 1990: Get your orchard soil colours done. *New Zealand kiwifruit*. June 1990:14

McLeod, M.; Singleton, P.L. 1990: Soil colours and kiwifruit death. *New Zealand soil news*. 39(2):64-65

McQueen, D. 1990: Traffic damage on effluent disposal sites. *In*: Cook, F.J.; Squire, P.J.; Barton, P.G.; Fenton, J.A.; McQueen, D.J. An introduction to soil physics and hydrology. (Land treatment collective technical reveiew; 2). p. 41-49

McQueen, D.J. 1990: Compaction testing of materials for land resotration. *In*: Gregg, P.E.H.; Stewart, R.B.; Currie, L.D. (*eds*). Issues in the restoration of disturbed land. (Occasional paper. Fertilizer and

Lime Research Centre, Massey University; 4). Fertilizer and Lime Research Centre, Massey University, Palmerston North. p. 293-303

McQueen, D.; Ross, C. 1990: Morton dam revisited. *New Zealand soil news*. 38(3):68-69

Manu, V.T.; Powell, H.K.P.; Banks, L.; Sheat, A.; Widdowson, J.P. 1990: Accession of SO_4^{2-} sulphur from Tongan rainfall. *Australian journal of soil research*. 28:727-736

Marino, M.R.; Brown, T.J.; Waddington, D.C.; Brockie, R.E.; Kelly, P.J. 1992: *Giardia intestinalis* in North Island possums, house mice and ship rats. *New Zealand veterinary journal*. 40:24-27

Markgraf, V.; Dodson, J.R.; Kershaw, A.P.; McGlone, M.S.; Nicholls, N. 1992: Evolution of late Pleistocene and Holocene climates in the circum-South Pacific land areas. *Climate dynamics*. 6:193-211

Meads, M. 1990: The weta book: a guide to the identification of wetas. 36 p. DSIR Land Resources, Lower Hutt.

Meads, M. 1990: Forgotten fauna: the rare, endangered and protected invertebrates of New Zealand. 96 p. DSIR Publishing, Wellington.

Meads, M. 1991: Giant land snails. Ecology notes; 2. 2 p. DSIR Land Resources, Lower Hutt.

Meads, M.J. 1991: Cicadas. Ecology notes; 23. 2 p. DSIR Land Resources, Lower Hutt.

Meads, M. 1991: Mosquitoes. Ecology notes; 24. 2 p. DSIR Land Resources, Lower Hutt.

Meads, M. 1991: Ants. Ecology notes; 25. 2 p. DSIR Land Resources, Lower Hutt.

Meads, M. 1991: Native land snails. Ecology notes; 29. 2 p. DSIR Land Resources, Lower Hutt.

Meads, M. 1991: Flax snails. Ecology notes; 30. 2 p. DSIR Land Resources, Lower Hutt.

Meurk, C.D.; Blaschke, P.M. 1990: How representative can restored islands really be?: an analysis of climo-edaphic environments in New Zealand. *In*: Towns, D.R.; Daugherty, C.H.; Atkinson, I.A.E. Ecological restoration of New Zealand islands. (Conservation sciences publication; 2). Department of Conservation, Wellington. p. 52-72

Meurk, C.D.; Buxton, R.P. 1990: What is happening to the natural landscape of Aotearoa? *Proceedings of the New Zealand Grassland Association*. 51:35-38

Meurk, C.D.; Given, D.R. 1990: Vegetation map of Campbell Island. Scale 1:25 000. Map (1 sheet). DSIR Land Resources, Christchurch.

Mew, G.; Ross, C.W. 1991: Beech forest after mining. *Terra Nova*. 4:52-53

Mew, G.; Ross, C.W. 1991: Soils, agriculture and forestry of the Westport region, West Coast, South Island, New Zealand. DSIR Land Resources scientific report; 1. 68 p. DSIR Land Resources, Lower Hutt.

Mew, G.; Ross, C.W. 1992: Minding the miners. *Terra Nova*. 15:43-45

Mills, J.A.; Lavers, R.B.; Lee, W.G.; Mara, M.K. 1991: Food selection by takahe *Notornis mantelli* in relation to chemical composition. *Ornis Scandinavica*. 22:111-128

Milne, J.D.G. 1991: Soils of Aitutaki, Cook Islands. New Zealand soil survey report; 51. 29 p. DSIR Land Resources, Lower Hutt.

Milne, J.D.G.; Clayden, B.; Singleton, P.L.; Wilson, A.D. 1991: Soil description handbook. 133 p. DSIR Land Resources, Lower Hutt.

Mitchell, T. 1990: New resource book free for schools. *Resource research*. 20:7

Mitchell, T. 1990: Gorse. Alpha. 74. 4 p. DSIR Publishing, Wellington.

Mizutani, H.; Kabaya, Y.; Moors, P.J.; Speir, T.W.; Lyon, G.L. 1991: Nitrogen isotope ratios identify deserted seabird colonies. *The Auk*. 108:960-964

Moar, N.T. 1990: Obituary: Ruth Mason, M.Sc. 1913-1990. *New Zealand journal of botany*. 28(4):485-490

Moar, N.T. 1991: [Book review]: *Nothofagidites* Erdtman ex Potonie, 1960: a catalogue of species with notes on the paleogeographic distribution of *Nothofagus* (Southern Beech), by Mary E. Dettmann, David T. Pocknall, Edgardo J. Romero and Maria del Carmen Zamaloa. *New Zealand journal of geology and geophysics*. 34(2):247

Moller, H.; Clapperton, B.K.; Alspach, P.A.; Tilley, J.A.V. 1991: Comparative seasonality of *Vespula germanica* (F.) and *Vespula vulgaris* (L.) colonies (Hymenoptera: Vespidae) in urban Nelson, New Zealand. *New Zealand journal of zoology*. 18(2):111-120

Moller, H.; Plunkett, G.M.; Tilley, J.A.V.; Toft, R.J.; Beggs, J.R. 1991: Establishment of the wasp parasitoid, *Sphecophaga vesparum* (Hymenoptera: Ichneumonidae), in New Zealand. *New Zealand journal of zoology*. 18(2):199-208

Moller, H.; Tilley, J.A.V.; Plunkett, G.M.; Clapperton, B.K. 1991: Nest sites of common and German wasps (Hymenoptera: Vespidae). *New Zealand journal of zoology*. 18(2):121-125

Moller, H.; Tilley, J.A.V.; Thomas, B.W.; Gaze, P.D. 1991: Effect of introduced social wasps on the standing crop of honeydew in New Zealand beech forests. *New Zealand journal of zoology*. 18(2):171-179

Molloy, B.P.J. 1990: Postscript and update. *In*: Peisley, A.B. *Thelymitra matthewsii* - the spiral sun orchid. *Orchids in New Zealand*. 16(2):48

Molloy, B.P.J. 1990: Pollination systems of New Zealand native orchids. *In*: St George, I.; McCrae, D. The New Zealand orchids: natural history and cultivation. v, 87 p. New Zealand Native Orchid Group, Dunedin. p. 36-56

Molloy, B.P.J. 1991: Naturalised orchids: do we have any? *Orchids in New Zealand*. 17(3):70-73

Molloy, B.P.J. 1991: [Book review]: *Australian orchid research, volume 2*: a New Zealand perspective. *Journal / New Zealand Native Orchid Group*. 39:8-10

Molloy, B.P.J. 1991: Landscape perception from the

point of view of a conservationist. *In*: Bishop, W.J.F.; Findlay, C. Land Settlement Board High Country Landscape Seminar, Lincoln College, Canterbury, 12-13 November 1984: report of proceedings and summary of working group findings. iii, 70 p. New Zealand Mountain Lands Institute; [Lincoln]. p. 18-21

Molloy, B.P.J. 1991: Ron Collins: a tribute from New Zealand. *The orchadian*. 10(3):70

Molloy, B.P.J. 1991: Notes on native orchids in Hanmer Forest. *Journal / New Zealand Native Orchid Group*. 40:3-8

Molloy, B.P.J. 1992: Orchid hunting with a difference. *Canterbury Orchid Society bulletin*. 408:[2]-[3]

Molloy, B.P.J. 1992: The horticultural potential of New Zealand native orchids. *In*: Proceedings of the 13th World Orchid Conference 1990. 336 p. 1990 World Orchid Conference Trust, Auckland. p. 82-85

Molloy, B.P.J.; Hatch, E.D. 1990: *Thelymitra tholiformis* (Orchidaceae): a new species endemic to New Zealand, with notes on associated taxa. *New Zealand journal of botany*. 28(2):105-114

Molloy, B.P.J.; Hatch, E.D. 1990: *Thelymitra tholiformis* Molloy et Hatch. = a new species of sun orchid endemic to New Zealand. *Journal / New Zealand Native Orchid Group*. 25:20-24

Molloy, B.P.J.; Partridge, T.R.; Thomas, W.P. 1991: Decline of tree lupin (*Lupinus arboreus*) on Kaitorete Spit, Canterbury, New Zealand, 1984-1990. *New Zealand journal of botany*. 29(3):349-352

Newman, R.H.; Tate, K.R. 1990: Carbon^{13} NMR characterisation of humic acids from soils of a development sequence. *Journal of soil science*. 42:39-46

Notman, P.R.; Yeates, G.W. 1992: Tomtit killed by a worm. *Notornis*. 39:16

Omura, H.; Nakata, K.; DeRose, R.C.; Trustrum, N.A. 1991: Physical properties of surface soil layer in pasture, Taranaki, New Zealand. Proceedings of the annual Japan Forestry Society Conference. p. 621-624

Orchard, V.A.; Burke, C.M.; Sparling, G.; Hewitt, A.E. 1990: Decomposition rates and microbial activity as indicators of soil recovery following rabbit and sheep exclusion from three sites on Earnsleugh Station. *In*: 1990 conference November 12-15: 'dry soils now - drier soils tomorrow?': innovation, production and conservation on droughty soils. New Zealand Society of Soil Science.

Orchard, V.A.; Cook, F.J.; Corderoy, D.M. 1992: Field and laboratory studies on the relationships between respiration and moisture for two soils of contrasting fertility status. *Pedobiologia*. 36:21-33

Orchard, V.A.; Slade, A.; Fullerton, R. 1991: Enhanced fungicide breakdown in soil and the response of the microbial biomass. New Zealand Microbiological Society Annual Conference 14-17 May 1991. New Zealand Microbiological Society. p. 74

Pain, C.F.; Stephens, P.R. 1990: Storm damage assessment using digitised aerial photographs: Eltham, New Zealand, 24-25 February 1986. *New Zealand geographer*. 46(1):21-25

Palser, B.F.; Philipson, W.R.; Philipson, M.N. 1991: Characteristics of ovary, ovule and mature megagametophyte in *Rhododendron* L. (Ericaceae) and their taxonomic significance. *Botanical journal of the Linnean Society*. 105(4):289-390

Parfitt, R.L. 1990: Soils formed in tephra in different climatic regions. Transactions, 14th International Congress of Soil Sciences, Kyoto, Japan, August 1990. Volume VII, Commission VII and Subcommission A-D:134-139

Parfitt, R.L. 1990: Allophane in New Zealand - a review. *Australian journal of soil research*. 28:343-360

Parfitt, R.L. 1990: Estimation of imogolite in soils and clays by DTA. *Communications in soil science and plant analysis*. 21:623-628

Parfitt, R.L. 1990: [Book review]: *Minerals in soil environments*, second edition, 1989. J.B. Dixon and S.B. Weed, Eds. Soil Science Society of America, Madison, Wis. *Soil science*. 150:562

Parfitt, R.L. 1990: Minerals in soil environments. *Soil science*. 150:562

Parfitt, R.L. 1991: Relationships between exchangeable K, Mg, Ca and soil solution K, Mg, Ca. Soil and plant testing for nutrient deficiencies and toxicities. *In*: White, R.E.; Currie, L.D. Soil and plant testing for nutrient deficiencies and toxicities. vii, 354 p. (Occasional report / Fertilizer and Lime Research Centre, Massey University; 5). Fertilizer and Lime Research Centre. Massey University; Palmerston North. p. 60-65

Parfitt, R.L. 1991: Definitions of allophane. *Clay Minerals Society news*. June 1991:12-14

Parfitt, R.L. 1992: Definitions of allophane. *AIPEA newsletter*. 28:16-17

Parfitt, R.L. 1992: Potassium-calcium exchange in some New Zealand soils. *Australian journal of soil research*. 30:145-158

Parfitt, R.L.; Clayden, B. 1991: Andisols: the development of a new order in soil taxonomy. *Geoderma*. 49:181-198

Parfitt, R.L.; McDonald, W.S. 1992: Soil acidity in New Zealand - a GIS representation. *Soil news*. 40:59-64

Parfitt, R.L.; Marsh, K. 1991: What happens to nutrients in the soil? *New Zealand kiwifruit*. 85:18-19

Parsons, M.J. 1990: Obituary [of Ruth Mason, 1913-1990]. *New Zealand Limnological Society newsletter*. 26:42

Parsons, M.J. 1991: Herbarium (CHR), Botany Institute, DSIR Land Resources. *Newsletter / New Zealand Botanical Society*. 23:12-13

Partridge, T.R. 1991: [Book review]: *Germination physiology and desert ecology*. *New Zealand journal of botany*. 29(4):467-468

Partridge, T.R. 1992: The sand dune and beach vegetation inventory of New Zealand. I, North Island. DSIR Land Resources scientific report; 15. 253 p. DSIR Land Resources, Christchurch.

Partridge, T.R. 1992: Successional interactions between bracken and broom on the Port Hills, Canterbury, New Zealand. *Journal of applied ecology*. 29(1):85-91

Partridge, T.R.; Allen, R.B.; Johnson, P.N.; Lee, W.G. 1991: Vegetation/environment relationships in lowland and montane vegetation of the Kawarau Gorge, Central Otago, New Zealand. *New Zealand journal of botany*. 29(3):295-310

Partridge, T.R.; Wilson, M.D. 1990: A germination inhibitor in the seeds of mahoe (*Melicytus ramiflorus*). *New Zealand journal of botany*. 28(4):475-478

Patel, R.N. 1990: Wood anatomy of the dicotyledons indigenous to New Zealand. 20, Cunoniaceae. *New Zealand journal of botany*. 28(3):347-355

Patel, R.N. 1991: Wood anatomy of the dicotyledons indigenous to New Zealand. 21, Loranthaceae. *New Zealand journal of botany*. 29(4):429-449

Percival, H.J. 1992: Soil water chemistry and mineral stability in soils: a physical chemistry approach. *Chemistry in New Zealand*. 56(1):6-10

Philipson, M.N. 1991: Ultrastructure of the *Gliocladium*-like endophyte of perennial ryegrass (*Lolium perenne* L.). I, Vegetative phase and leaf blade sporulation. *The new phytologist*. 117(2):271-280

Philipson, M.N. 1991: Ultrastructure of the *Gliocladium*-like endophyte of perennial ryegrass (*Lolium perenne* L.). II, Sporulation in the leaf sheath. *The new phytologist*. 117(2):281-288

Philipson, M.N. 1991: Ultrastructure of a symptomless fungal endophyte of *festuca arundinacea*. *Botanical gazette*. 152(3):296-303

Philipson, M.N. 1991: Sepal and lateral pores in the fungal endophytes of two pasture grasses. *Canadian journal of botany*. 69:2740-2743

Pickrill, R.A.; Fenner, J.M.; McGlone, M.S. 1990: Late Quaternary evolution of a lake / fjord environment, Preservation Inlet, New Zealand. *Geological Society of New Zealand miscellaneous publication*. 50A:109

Rijkse, W.C. 1990: Soils of Sigatoka Agricultural Research Station, Viti Levu, Fiji. New Zealand soil survey report; 81. 58 p.

Ross, C.W. 1991: 1991 NZIAS presidential address. *New Zealand agricultural science*. 26:3-4

Ross, C.; McCann, J. 1992: Research reform - its effects on science professionals. *In*: Horticultural research - your country, your future. Proceedings 1992 AIAS Conference, Orange, NSW. Australian Institute of Agricultural Science, Melbourne. p. 46-51

Ross, C.; McQueen, D.; Blaschke, P.; Lilley, G. 1990: Revegetation of lake sediment, Morton Reservoir, Wainuiomata, Wellington. *New Zealand soil news*. 38(2):37-42

Ross, C.W.; Mew, G. 1991: Land rehabilitation after alluvial gold mining in Westland, New Zealand. *In*: Environmental workshop 1991 proceedings Volume I. Australian Mining Industry Council. p. 175-187

Ross, C.; Wales, J. 1990: Drainage investigations for land restoration after open cast mining in Southland. *In*: Horne, D.J.; Furkert, I.F.H. (*eds*). Proceedings of the Fifth National Land Drainage Seminar held at Massey University, Palmerston North, New Zealand, 16-17 August, 1990. p. 112-132

Ross, D.J. 1990: Influence of soil mineral-nitrogen content on soil respiratory activity and measurements of microbial carbon and nitrogen by fumigation-incubation procedures. *Australian journal of soil research*. 28:311-321

Ross, D.J. 1990: Measurements of microbial biomass C and N in grassland soils by fumigation-incubation procedures: influence of inoculum size and the control. *Soil biology and biochemistry*. 22:289-294

Ross, D.J. 1990: Estimation of soil microbial C by a fumigation-extraction method: influence of seasons, soils and calibration with the fumigation-incubation procedure. *Soil biology and biochemistry*. 22:295-300

Ross, D.J. 1991: Microbial biomass in a stored soil: a comparison of different estimation procedures. *Soil biology and biochemistry*. 23:1005-1007

Ross, D.J.; Hart, P.B.S.; Sparling, G.P.; August, J.A. 1990: Soil restoration under pasture after topsoil removal: some factors influencing C and N mineralization and measurements of microbial biomass. *Plant and soil*. 127:49-59

Ross, D.J.; Speir, T.W.; Cowling, J.C.; Feltham, C.W. 1992: Soil restoration under pasture after lignite mining: management effects on soil biochemical properties and their relationships with herbage yields. *Plant and soil*. 140:85-97

Rudge, M.R. 1990: The Shorthorns of Enderby Island. *The Ark*. 17(7):241-242

Rudge, M.R. 1990: Genetic conservation efforts and problems in New Zealand and Australia. *In*: Anderson, L. (*ed*.). Genetic conservation of domestic livestock. CAB International, Wallingford, U.K. p. 18-21

Rudge, M.R. 1990: The importance of feral animals on New Zealand Islands. *In*: Towns, D.R.; Daugherty, C.H.; Atkinson, I.A.E. Ecological restoration of New Zealand islands: papers presented at a conference on ecological restoration of New Zealand islands, University of Auckland, 20-24 November 1989, Auckland, New Zealand. (Conservation Sciences Publication; 2). Department of Conservation, Wellington.

Rudge, M.R. 1990: Feral goat. *In*: King, C.M. (*ed*.).

The handbook of New Zealand mammals. Oxford University Press, Auckland. p. 406-423

Rudge, M.R. 1990: Feral sheep. *In*: King, C.M. (*ed.*). The handbook of New Zealand mammals. Oxford University Press, Auckland. p. 424-431

Searle, P.L. 1990: Reducing interferences by amino acids in the determination of ammonium by an automated indophenol method. *Communications in soil science and plant analysis.* 21:831-835

Searle, P.L. 1991: A simple manual method for the determination of phosphate-extractable (ion-exchange membrane) sulfate in soils. *Communications in soil science and plant analysis.* 22:1347-1355

Searle, P.L. 1991: Appendix VIII: sampling proceedures. *In*: Milne, J.D.G.; Clayden, B.; Singleton, P.L.; Wilson, A.D. Soil description handbook. DSIR Land Resources, Lower Hutt. p. 112-119

Searle, P.L. 1991: Appendix VX: chemical and physical tests for the field or field laboratory. *In*: Milne, J.D.G.; Clayden, B.; Singleton, P.L.; Wilson, A.D. Soil description handbook. DSIR Land Resources, Lower Hutt. p. 120-133

Searle, P.L. 1992: The extraction of sulphate and mineralisable sulphur from soil with an anion-exchange membrane. *Communications in soil science and plant analysis.* 23:1347-1355

Searle, P.L.; Speir, T.W.; Kettles, H.A.; Mackay, A.D. 1991: Seasonal variation of extractable P, extractable sulphate and mineralisable S in a sabbatical fallowing trial. *In*: White, R.E.; Currie, L.D. Soil and plant testing for nutrient deficiencies and toxicities. (Occasional report / Fertilizer and Lime Research Centre, Massey University; 5). Fertilizer and Lime Research Centre. Massey University, Palmerston North. p. 122-129

Shepherd, T.G. 1991: Sustainable soil and crop management on arable land. *In*: Forum on Sustainable Resource Management. [Manawatu-Wanganui Regional Council, Palmerston North]. p. 95-107

Shepherd, T.G. 1992: Soils of the Pasture-Cropping Systems Unit, Aorangi Research Station, Manawatu District. DSIR Land Resources scientific report; 30. 79 p. DSIR Land Resources, Lower Hutt.

Shepherd, T.G. 1992: Site selection for tree and vine crops. *The orchardist of New Zealand.* 65(3):24-28

Shepherd, T.G.; Neall, V.E. 1991: Soils of Tutu Estate, Taveuni, Fiji. New Zealand soil survey report; 85. 111 p. DSIR Land Resources, Lower Hutt.

Simpson, M.J.A. 1990: Dumont d'Urville, Jules Sébastien César 1970-1842. *In*: The dictionary of New Zealand biography volume one 1769-1869. Allen & Unwin, Department of Internal Affairs. p. 113-114

Singleton, P.L. 1991: Water tables and soil colour as an indicator of saturation in some soils of the Waikato, New Zealand. *Australian journal of soil research.* 29:467-481

Singleton, P.L. 1991: Soil map of Ruakura Agricultural Research Centre, North Island, New Zealand. Scale 1:5000. DSIR Land Resources map; 304/1.

Singleton, P.L. 1991: Soil map of Ruakura Agricultural Research Centre, North Island, New Zealand. Scale 1:5000. DSIR Land Resources map; 304/2. Distribution of main subsoil material to one metre.

Singleton, P.L. 1991: Soil of Ruakura - a window on the Waikato. DSIR Land Resources scientific report; 5. 127 p. DSIR Land Resources, Lower Hutt.

Smith, S.M.; Schreier, H.E.; Brown, S. 1991: Spatial analysis of forage parameters using geographic information system and image-analysis techniques. *Grass and forage science.* 46:183-189

Sparling, G.P. 1990: Soil biomass evalaution. *In*: Pacificland Workshop on the Establishment of Soil Management Experiments on Sloping Lands (1989: Aiyura, Papua New Guinea), Pacificland Workshop on the Establishment of Soil Management Experiments on Sloping Lands: papers and reports of a training workshop held at Aiyura, Papua New Guinea. (IBSRAM technical notes; 4). International Board for Soil Research and Management, Bangkok. p. 163-184

Sparling, G.P. 1990: Monitoring to evaluate the sustainability of farming systems *In*: Pacificland Workshop on the Establishment of Soil Management Experiments on Sloping Lands (1989: Aiyura, Papua New Guinea), Pacificland Workshop on the Establishment of Soil Management Experiments on Sloping Lands: papers and reports of a training workshop held at Aiyura, Papua New Guinea. (IBSRAM technical notes; 4). International Board for Soil Research and Management, Bangkok. p. 201-213

Sparling, G.P.; Feltham, C.W.; Reynolds, J.; West, A.W.; Singleton, P.L. 1990: Estimation of soil microbial C by a fumigation-extraction method: use on soils of high organic matter content, and a reassessment of the k_{EC} factor. *Soil biology and biochemistry.* 22:301-307

Sparling, G.P.; West, A.W. 1990: A comparison of gas chromatography and differential respirometer methods to measure soil respiration and to estimate the soil microbial biomass. *Pedobiologia.* 34:103-112

Speir, T.W.; Cowling, J.C. 1991: Phosphatase activities of pasture plants and soils: relationship with plant productivity and soil P fertility indices. *Biology and fertility of soils.* 12:189-194

Speir, T.W.; Orchard, V.A.; Sparling, G.P. 1991: Managing change: the soil perspective. *New Zealand agricultural science.* 26:32-33

Speir, T.W.; Ross, D.J. 1990: Temporal stability of

enzymes in a peatland soil profile. *Soil biology and biochemistry*. 22:1003-1005

Stephens, P.R. 1991: Remote sensing in New Zealand. *Geocarto international*. 6(3):90-92

Stephens, P.R. 1992: Remote sensing and geographical information systems for resource management and environmental monitoring. *Asian-Pacific remote sensing journal*. 3(2):63-73

Stephens, P.; Cocks, J.S. 1991: Changes in vegetation and sand-dunes from digitized aerial photographs and SPOT data: changes over a period of 23 years. *In*: Murai, S. Asian Association on Remote Sensing, Applications of remote sensing in Asia and Oceania - Environmental change monitoring. 372 p. Asian Association on Remote Sensing, Tokyo. p. 175-179

Stephenson, W.R. 1990: The three-dimensional resonance of axisymmetric sediment-filled valleys. *Soils and foundations*. 30:188-190

Stephenson, W.R. 1991: Cellular normal modes: an explanation for alluvium response to earthquakes. *In*: Prakash, Shamsher Proceedings: Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, March 11-15, 1991, St. Louis, Missouri. University of Missouri - Rolla, Rolla, Missouri. p. 1155-1165

Stephenson, W.R. 1991: An assessment of the proportion of earthquakes likely to be amplified by flexible sediments. *In*: Pacific Conference on Earthquake Engineering, Auckland, New Zealand, 20-23 November 1991, Proceedings, Volume 3. New Zealand National Society for Earthquake Engineering, Wellington. p. 149-158

Stephenson, W.R.; Barker, P.R. 1991: Results from the Pukehou array. *In*: Pacific Conference on Earthquake Engineering, Auckland, New Zealand, 20-23 November 1991, Proceedings, Volume 3. New Zealand National Society for Earthquake Engineering, Wellington. p. 229-238

Sykes, M.T.; Wilson, J.B.; Lee, W.G.; Allen, R.B. 1991: A remnant New Zealand carr. *Journal of vegetation science*. 2:209-216

Sykes, W.R. 1990: Botanical highlights in the Cook Islands. *Journal / Canterbury Botanical Society*. 24:8-12

Sykes, W.R. 1991: Gymnospermae of Guangxi, south China. *Guihaia*. 11(4):339-377

Sykes, W.R. 1991: [Book review]: *Economic plants of New Zealand*, by S.G. Brooker, R.C. Cambie and R.C. Cooper, 1988. *Archives of natural history*. 18(1):130-131

Sykes, W.R. 1992: Succulent plants on Rangitoto Island. *Journal / Auckland Botanical Society*. 47(1):6-16

Sykes, W.R. 1992: Botanical observations on Atiu, Cook Islands. *Newsletter / New Zealand Botanical Society*. 27:12-16

Tate, K.R. 1992: Soils and climate change: a New Zealand perpective. *In*: Williams, W. (*ed.*). Proceedings of the Royal Society of New Zealand's (IGBP) conference: global change impacts on agriculture and forestry. (Bulletin / Royal Society of New Zealand; 30). p. 57-62

Tate, K.R.; Ross, D.J.; Ramsay A.J.; Whale, K.N. 1991: Microbial biomass and bacteria in two pasture soils: an assessment of measurement procedures, temporal variations, and the influence of P fertility status. *Plant and soil*. 132:233-241

Tate, K.R.; Speir, T.W.; Ross, D.J.; Parfitt, R.L.; Whale, K.N.; Cowling, J.C. 1991: Temporal variations in some plant and soil P pools in two pasture soils of widely different P fertility status. *Plant and soil*. 132:219-232

Tate, K.R.; Yamamoto, K.; Churchman, G.J.; Meinhold, R.; Newman, R.H. 1990: Relationships between the type and carbon chemistry of humic acids from some New Zealand and Japanese soils. *Soil science and plant nutrition*. 36(4):611-621

Taylor, R.H. 1990: Records of subantarctic fur seals in New Zealand (Note). *New Zealand journal of marine and freshwater research*. 24(4):499-502

Taylor, R.H. 1992: New Zealand fur seals at the Antipodes Islands. *Journal of the Royal Society of New Zealand*. 22(2):107-122

Taylor, R.H.; Thomas, B.W. 1990: The Breaksea Island campaign: a major advance in rodent eradication. *In*: Towns, D.R.; Daugherty, C.H.; Atkinson, I.A.E. Ecological restoration of New Zealand islands. (Conservation sciences publication; 2). Department of Conservation, Wellington. p. 312

Taylor, R.H.; Wilson, P.R. 1990: Recent increase and southern expansion of Adelie penguin populations in the Ross Sea, Antarctica related to climatic warming. *New Zealand journal of ecology*. 14:25-29

Taylor, R.H.; Wilson, P.R.; Thomas, B.W. 1990: Status and trends of Adelie penguins populations in the Ross Sea region. *Polar Record*. 26 (159):293-304

Theng, B.K.G. 1991: Soil science in the tropics: the next 75 years. *Soil science*. 151:76-90

Theng, B.K.G. 1991: Soil science in the tropics: the next 75 years: response to the letter to the editor. *Soil science*. 152:136

Theng, B.K.G. 1991: Impressions of Japan. *New Zealand soil news*. 89:88-89

Theng, B.K.G.; Tate, K.R. 1990: Interactions of clays with soil organic constituents. *Clay research*. 8:1-10

Thomas, B.W. 1990: Penguin census conducted by aerial photography. *Antarctica sun times*. 4/9:3, 6

Thomas, R.F.; Mew, G.; Barker, P.R. 1990: Effect of different drainage systems on bearing resistance of some West Coast, South Island soils. *New Zealand journal of agricultural research*. 33(3):479-488

Thompson, C.F.; Flux, J.E.C. 1991: Body mass,

composition, and survival of nestling and fledgling starlings (*Sturnus vulgaris*) at Belmont, New Zealand. *New Zealand journal of ecology*. 15 (1):41-47

Thomson, A.D. 1990: Death of cabbage trees. *Te karanga*. 6(1):17

Thomson, A.D. 1990: A comparison of the approach to taxonomic botany by T.F. Cheeseman and L. Cockayne. *In*: Short, P.S. History of systematic botany in Australasia: proceedings of a symposium held at the University of Melbourne, 25-27 May 1988. v, 326 p. Australian Systematic Botany Society; South Yarra, Victoria. p. 235-238

Thomson, A.D. 1991: Genetics in New Zealand. *Proceedings of the Royal Society of New Zealand*. 117/118:224-235

Timmins, S.M.; Williams, P.A. 1991: Weed numbers in New Zealand's forest and scrub reserves. *New Zealand journal of ecology*. 15(2):153-162

Timmins, S.; Williams, P.A. 1991: Reserve design and management for weed control. *In*: Bassett. C.; Whitehouse, L.J.; Zabkiewicz, J. (*eds*). Alternatives to the chemical control of weeds. Proceedings of an International Conference, Rotorua, New Zealand, July 1989. Ministry of Forestry. (Forest Research Institute Bulletin; 155). p. 133-138

Tonkin, P.J.; Basher, L.R. 1990: Soil-stratigraphic techniques in the study of soil and landform evolution across the Southern Alps, New Zealand. *Geomorphology*. 3:547-575

Towns, D.R.; Daugherty, C.H.; Atkinson, I.A.E. 1990: Ecological restoration of New Zealand islands: papers presented at conference on ecological restoration of New Zealand islands, University of Auckland, 20-24 November 1989, Auckland, New Zealand. (Conservation sciences publication; 2). 320 p. Department of Conservation, Wellington.

Towns, D.R.; Atkinson, I.A.E. 1991: New Zealand's restoration ecology. *New scientist*. 130 (1765):36-39

Trangmar, B.B. [Comp.] 1992: Proceedings of the soil fertility and land evaluation workshop. Nuku'alofa, Kingdom of Tonga, 3-7 February 1992. 241 p. DSIR Land Resources, Lower Hutt.

Trotter, C.M. 1990: Geographical information systems and image data. Plenary paper. Proceedings of the fifth Australasian remote sensing conference, Vol 1. Perth, Australia. p. 75-87

Trotter, C.M. 1991: Remotely-sensed data as an information source for geographical information systems in natural resource management: a review. *International journal of geographical information systems*. 5 (2):225-239

Trotter, C.M.; Pinkney, E.J.; Tod, H.G. 1992: Weathering and strength loss in stable and unstable ground at an earthflow site. *In*: Bell, D.H. (*ed*.). Landslides. Proceedings of the Sixth International Symposium, 10-14 February, 1992, Christchurch, New Zealand. Balkema, Rotterdam. p. 1489-1495

Trustrum, N.A. 1990: Landscape and geomorphic interpretation for assessment of environmental hazards of surface mining. *In*: Rijnberg, T.F. Proceedings of the Joint Seminar on Environmental Impacts of Mining in Watershed Management held from November 5th, 1990 till November 14th, 1990 in Bogor and Tainjung Enim, Indonesia. (SECM Special publications; 4). School of Environmental Conservation Management; Bogor, Indonesia. p. 22-33

Trustrum, N.A. 1990: Application of remote sensing to monitor environmental impacts of surface mining. *In*: Rijnberg, T.F. Proceedings of the Joint Seminar on Environmental Impacts of Mining in Watershed Management held from November 5th, 1990 till November 14th, 1990 in Bogor and Tainjung Enim, Indonesia. (SECM Special publications; 4). School of Environmental Conservation Management; Bogor, Indonesia. p. 59-66

Trustrum, N.A. 1990: Cyclone impacts. *In*: Crozier, M.J. (*ed*.). Proceedings of VUW/DSIR Seminar Series on Natural Hazards, Wellington, July 1990. Natural Hazards 90, Natural Hazard Assessment in New Zealand. Research School of Earth Sciences, Victoria University of Wellington publication. p. 29-30

Trustrum, N.A.; Blaschke, P.M.; DeRose, R.C.; West, A.W. 1990: Regolith changes and pastoral productivity declines following deforestation in steeplands of North Island, New Zealand. Transactions of the 14th International Congress of Soil Science. Volume 1, Commission I: Kyoto, Japan, August 1990:129-130

Trustrum, N.; Blaschke, P. 1992: Managing hill country erosion. *Farm progress*. June 1992:45-47

Trustrum, N.A.; Page, M.J. 1992: Reconstruction of erosion and sedimentation history of soft-rock landscapes in the northern Hawke's Bay. *In*: Landslides and landscape development in soft-rock terrain of the east coast, North Island, New Zealand. Field-trip Guide of Sixth International Symposium of Landslides 15-20 February 1992. p. 78-84

Trustrum, N.A.; Whitehouse, I.E.; Blaschke, P.M.; Stephens, P.R. 1990: Flood and landslide hazard mapping, Solomon Islands. *In*: Zeimer, R.R.; O'Loughlin, C.L.; Hamilton, L.S., International Association of Hydrological Sciences, Research needs and applications to reduce erosion and sedimentation in tropical steeplands: Proceedings of the Fiji Symposium, June 1990. (IAHS-AISH publication; 192). IAHS Press, Wallingford, Oxfordshire. p. 138-146

Wardle, P. 1991: Vegetation of New Zealand. xx, 672 p. Cambridge University Press, Cambridge.

Wardle, P.; Godley, E.J. 1990: Preserving native

vegetation: the importance of local stock. *New Zealand tree grower*. 10(4):28

Wardle, P.; Lee, W.G. 1990: Environmental and floristic gradients in Westland, New Zealand, and the discontinous distribution of *Nothofagus*: [letter to the editor]. *New Zealand journal of botany*. 28:479-481.

Watt, J.P.C. 1990: President's address - "1990 and all that!" *New Zealand Soil News*. 38(6):149-154

Weatherall, I.L.; Lee, W.G. 1991: Instrumental evaluation of some New Zealand fruit colours using CIELAB values. *New Zealand journal of botany*. 29(2):197-205

Webb, C.J. 1990: [Book review]: *Improved edible plants. The Press* (Christchurch). 10 Nov. 1990:27

Webb, C.J. 1992: How flowers work. *Journal / Auckland botanical society*. 47:1-5

Webb, C.J.; Johnson, P.N.; Sykes, W.R. 1990: Flowering plants of New Zealand. 146 p. DSIR Botany, Christchurch.

Webb, C.J.; Simpson, M.J.A. 1991: Seed morphology in relation to taxonomy in New Zealand species of *Weinmannia*, *Ackama*, and the related South American *Caldcluvia paniculata* (Cunoniaceae). *New Zealand journal of botany*. 29(4):451-453

Webb, T.H. 1992: Soils of upper Waitaki Basin. DSIR Land Resources scientific report; 3. 100 p. DSIR Land Resources, Lower Hutt.

Whitehead, N.E.; Barrie, J.; Rankin, P. 1990: Anomalous Hg contents in soils of Niue Island, South Pacific. *Geochemical journal*. 24:371-378

Whitehouse, I.E. 1990: Geomorphology of the Himalaya: a climato-tectonic framework. *New Zealand geographer*. 46(2):75-85

Whitehouse, I.E.; Basher, L.R.; Tonkin, P.J. 1990: A landform classification for PNA surveys in Southern Alps. Department of Conservation Science and Research Series; 44. 41 p.

Widdowson, J.P. 1990: The impacts of surface mining activities on soil and water. *In*: Rijnberg, T.F. Proceedings of the Joint Seminar on Environmental Impacts of Mining in Watershed Management held from November 5th, 1990 till November 14th, 1990 in Bogor and Tainjung Enim, Indonesia. (SECM Special publications; 4). School of Environmental Conservation Management, Bogor, Indonesia. p. 34-58

Widdowson, J.P. 1990: Rehabilitation planning and supervising mining operations to minimise adverse environmental effects. *In*: Rijnberg, T.F. Proceedings of the Joint Seminar on Environmental Impacts of Mining in Watershed Management held from November 5th, 1990 till November 14th, 1990 in Bogor and Tainjung Enim, Indonesia. (SECM Special publications; 4). School of Environmental Conservation Management, Bogor, Indonesia. p. 67-75

Widdowson, J.P. 1990: Application of land rehabilitation techniques to return mined lands to productive farming and forestry uses. *In*: Rijnberg, T.F. Proceedings of the Joint Seminar on Environmental Impacts of Mining in Watershed Management held from November 5th, 1990 till November 14th, 1990 in Bogor and Tainjung Enim, Indonesia. (SECM Special publications; 4). School of Environmental Conservation Management, Bogor, Indonesia. p. 76-92

Widdowson, J.P. 1990: Recommendations for rehabilitation of mine sites at Bukit Asam. *In*: Rijnberg, T.F. Proceedings of the Joint Seminar on Environmental Impacts of Mining in Watershed Management held from November 5th, 1990 till November 14th, 1990 in Bogor and Tainjung Enim, Indonesia. (SECM Special publications; 4). School of Environmental Conservation Management, Bogor, Indonesia. p. 213-219

Widdowson, J.P.; McQueen, D.J. 1990: Rehabilitation after opencast mining in Southland. *In*: Gregg, P.E.H.; Stewart, R.B.; Currie, L.D. (*eds*). Issues in the restoration of disturbed land. Fertilizer and Lime Research Centre, Massey University; 4). Fertilizer and Lime Research Centre, Massey University, Palmerston North. p. 132-146

Williams, P.A. 1991: Subalpine and alpine vegetation of granite ranges in western Nelson, New Zealand. *New Zealand journal of botany*. 29(3):317-330

Williams, P.A.; Courtney, S.; Glenny, D.; Hall, G.; Mew, G. 1990: Pakihi and surrounding vegetation in north Westland, South Island. *Journal of the Royal Society of New Zealand*. 20(2):179-203

Wilson, H.D. 1990: The botany of Otanerito Station, Banks Peninsula. *Journal / Canterbury Botanical Society*. 24:14-26

Wilson, H.D. 1990: Gorse on Hinewai Reserve. *Journal / Canterbury Botanical Society*. 24:45-47

Wilson, H.D. 1991: [Book review]: *Flowering plants of New Zealand* by Colin Webb, Peter Johnson and Bill Sykes. *Service*. 4(3):32

Wilson, H.D. 1991: Distribution maps of small-leaved shrubs in Canterbury and Westland. *Journal / Canterbury Botanical Society*. 25:3-81

Wilson, J.B.; Partridge, T.R.; Sykes, M.T. 1990: The use of the Cole / Hurlbert C_8 association coefficient in inverse ecological classification. *Journal of vegetation science*. 1(3):367-374

Wilson, K.J.; Taylor, R.H.; Barton, K.J. 1990: The impact of man on Adelie penguins at Cape Hallett, Antarctica. *In*: Kerry, K.R.; Hempel, G. Antarctic ecosystems. Ecological change and conservation. Springer, Berlin. p. 183-190

Yeates, G.W. 1990: Nematodes in New Zealand forest nurseries. *New Zealand journal of forestry science*. 20:249-256

Yeates, G.W. 1991: Nematode populations at three

forest sites in New Caledonia. *Journal of tropical ecology*. 7:411-413
Yeates, G.W. 1991: Impact of historical changes in land use on the soil fauna. *New Zealand journal of ecology*. 15:99-106
Yeates, G.W. 1992: Earthworms. *New Zealand science teacher*. 69:49-51
Yeates, G.W. 1992: [Book review]: *Biological control of plant parasitic nematodes: progress, problems and prospects*. By G.R. Stirling. *New Zealand journal of crop and horticultural science*. 20:102-103
Yeates, G.W. 1992: Nematodes from New Caledonia. 1. Introduction and Monochoidea. *Fundamental and applied nematology*. 15:101-126
Yeates, G.W. 1992: Earthworms. Ecology notes; 28. 2 p. DSIR Land Resources, Lower Hutt.
Yeates, G.W.; Bamforth, S.S.; Ross, D.J.; Tate, K.R.; Sparling, G.P. 1991: Recolonization of methyl bromide sterilized soil under four different field conditions. *Biology and fertility of soils*. 11:181-189
Yeates, G.W.; Hughes, K.A. 1990: Effect of three tillages regimes on plant and soil nematodes in an oats/maize rotation. *Pedobiologia*. 34:379-387

DSIR Land Resources Unpublished Reports - Restricted Distribution

Allen, R.B. 1991: Kanuka ecology and management, eastern Otago. DSIR Land Resources vegetation report; 723. 5 p.

Allen, R.B. 1991: Assessment of biological values of indigenous forest remnants on private land in southeast Otago and eastern Southland. DSIR Land Resources contract report; 91/25.

Allen, R.B. 1991: Restoration of native vegetation, Waikouaiti Beach and Hawkesbury Lagoon, east Otago. DSIR Land Resources contract report; 91/92.

Allen, R.B.; 1991: Vegetation survey Taiaroa Head nature reserve. DSIR Land Resources vegetation report; 739. 7 p.

Allen, R.B. 1992: Hawkweed control trials, Central Otago. DSIR Land Resources contract report; 92/13.

Allen, R.B. 1992: Recovery plan for indigenous saline soil *Lepidium* species. DSIR Land Resources contract report; 92/18.

Allen, R.B. 1992: Vegetation of POL 064, Michael Peak, St Bathans Range. DSIR Land Resources contract report; 92/22.

Allen, R.B. 1992: Specification for excavations through forest vegetation. DSIR Land Resources contract report; 92/23.

Allen, R.B.; Johnson, P.N. 1991: Otago Harbour : vegetation of the harbour catchment. DSIR Land Resources vegetation report; 734. i, 12 p.

Atkinson, I.A.E. 1991: A re-appraisal of the conservation value of Mana Island. DSIR Land Resources technical record; 64. 8 p.

Atkinson, I.A.E.; Taylor, R.H. 1991: Distribution of alien mammals on New Zealand islands. Part 1. DSIR Land Resources contract report; 91/50.

Barker, P.R. 1990: Report on measurements of thermal resistivity on cement stabilised backfill. DSIR Land Resources contract report; 90/20.

Barker, P.R. 1991: Report on measurement of thermal resistivity of bentonite sand mixtures. DSIR Land Resources contract report; 91/19.

Barker, P.R. 1991: Report on thermal resistivity values of soils. DSIR Land Resources contract report; 91/22.

Barker, P.R. 1992: Report on measurements of thermal resistivity of two sand samples: a report to Brian Perry Ltd. DSIR Land Resources contract report; 91/2.

Barker, P.R.; Ross, C.W. 1991: First monitoring report on effects of turf farming at Judgeford. DSIR Land Resources contract report; 91/37.

Barker, P.R.; Stephenson, W.R. 1991: Wellington Regional Council regional natural disaster reduction plan : seismic hazard. DSIR Land Resources contract report; 91/21.

Barker, P.R.; Wales, J.F.; Ross, C.W. 1991: Preliminary geological survey for proposed Akatarawa cemetery. Stage II. DSIR Land Resources contract report; 91/36.

Barlow, N.D.; Moller, H.; Beggs, J.R. 1992: A preliminary model for the impact of *Sphecophaga vesparum* on the common wasp in honeydew beech forests. DSIR Land Resources contract report; 92/05.

Barringer, J.R.F. 1991: Modelling soil moisture deficits and wheat yields on the mid-Canterbury Plains. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 33

Basher, L.R.; Beecroft, F.G. 1991: The effectiveness of erosion pins for erosion assessment in the Otago uplands : a report on a visit to sites on the St Bathans Range. DSIR Land Resources technical record; 69. 18 p.

Basher, L.R.; Meurk, C.D.; Tate, K.R. 1990: The effects of burning on soil properties and vegetation : a review of the scientific evidence relating to the sustainability of ecosystems and land use in the eastern South Island hill and high country. DSIR Land Resources technical record; 18. 93 p.

Beecroft, F.G. 1991: Land evaluation of Lot 1, Plan 10693, Section 28, Sawyers Bay District. DSIR Land Resources contract report; 91/14.

Beecroft, F.G. 1991: Assessment of impact on soil/water of diesel pollution. DSIR Land Resources contract report; 91/16.

Beecroft, F.G. 1991: Investigation of subsoils for septic tank effluent disposal at Aramoana township. DSIR Land Resources contract report; 91/77.

Beecroft, F.G. 1991: Land stability assessment, Mitchell property subdivision, Saddle Hill, Dunedin. DSIR Land Resources contract report; 91/89.

Beecroft, F.G. 1991: Supplementary land stability explanations, Mitchell property subdivision, Saddle Hill, Dunedin. DSIR Land Resources contract report; 91/105.

Begg, J.; Wills, B.J.; McIntosh, P.D.; Allen, R.B.; Wallace, H.J. 1991: Preliminary assessment of DSIR eucalypt trials in Southland. DSIR Land Resources vegetation report; 756. 6 p.

Beggs, J.R. 1991: Impact of *Vespula* wasps on native insects and birds. DSIR Land Resources contract report; 91/62.

Blaschke, P.M.; Eyles, G.O.; DeRose, R.C.; Hicks, D.L. 1992: Physically sustainable land uses in

Taranaki. DSIR Land Resources contract report; 92/27.

Brockie, R.E.; Ward, G.D.; Herritty, P.J.; Smith, R.N. 1991: Recolonisation and dispersal of possums on Hawke's Bay farmland 1988-1991 : a progress report. DSIR Land Resources technical record; 51. 23 p.

Buxton, R.P. 1991: Upper Buller sphagnum survey. DSIR Land Resources contract report; 91/110.

Buxton, R.P.; Espie, P.R.; Johnson, P.N. 1991: Sphagnum moss studies in Westland 1990/91 : botanical report. DSIR Land Resources contract report; 91/107.

Buxton, R.P.; Johnson, P.N. 1991: Sphagnum research programme : harvesting impacts. DSIR Land Resources contract report; 91/64.

Buxton, R.P.; Johnson, P.N.; Espie, P.R. 1990: Sphagnum moss studies in Westland : botanical report. DSIR Land Resources vegetation report; 733. 39 p.

Campbell, D.J. 1991: Restoration planting at the water treatment plant at Morton Dam, Wainuiomata. DSIR Land Resources contract report; 91/6.

Campbell, D.J. 1992: Revegetation of Somes Island. DSIR Land Resources technical record; 85. 15 p.

Clarkson, B.D. 1991: Studies on threatened plants. Part 1. Ecology and conservation of heart-shaped kohuhu (*Pittosporum obcordatum* s.s.) in the East Coast Regional conservancy. DSIR Land Resources contract report; 91/57.

Clarkson, B.D. 1991: Sudden decline of cabbage trees : ecology of cabbage tree. DSIR Land Resources contract report; 91/67.

Clarkson, B.D.; Wallace, S.W.; Spring-Rice, B. 1991: Biological assessment of the geothermal areas on Paehinahina–Mourea Trust Lands. DSIR Land Resources contract report; 90/28.

Clayden, B. 1991: Criteria for the definition of soil series in the New Zealand Soil Classification. DSIR Land Resources technical record; 50. 28 p.

Clunie, N.M.U. 1991: Vegetation of the Te Paki Ecological Region. DSIR Land Resources contract report; 91/58.

Cook, F.J. 1990: Comparison of 1-dimensional models for prediction of water transport in soils. DSIR Land Resources technical record; 12. 36 p.

Cowan, P.E. 1991: Progress reports on possum research. DSIR Land Resources contract report; 91/20.

Cowan, P.E. 1991: Progress report on sexual maturation and dispersal of juvenile male possums. DSIR Land Resources contract report; 91/21.

Cowan, P.E. 1991: Rodent attack on nylon pipe for domestic gas installation. DSIR Land Resources contract report; 91/34.

Cowan, P.E. 1991: Progress report on sexual maturation and dispersal of juvenile male possums. DSIR Land Resources contract report; 91/74.

Cowan, P.E. 1991: A review of sexual maturation of male possums *Trichosurus vulpecula*. DSIR Land Resources contract report; 91/75.

Cowan, P.E. 1992: Sexual maturation of and dispersal of juvenile male possums. Final report on studies of physical maturation. DSIR Land Resources contract report; 92/09.

Cowan, P.E.; Woodhouse, A.D. 1991: Possum pheromones as attractants : progress report. DSIR Land Resources contract report; 91/90.

Crawley, M.C.; Atkinson, I.A.E.; Clunie, N.M.U.; Kelly, G.C.; Meurk, C.D. 1991: 1990/91 progress report on plant materials suitable for revegetation programme 331, objective 8, project 64170. DSIR Land Resources technical record; 53. 31 leaves.

Cromey, M.; Rennie, W.; Cooper, D. 1991: Cytology of pear fruit. DSIR Land Resources contract report; 91/26.

Daly, B.K. 1991: Methods for soil and plant analysis. Fiji Soil and Crop Evaluation Project technical report; 3. 68 p.

Daly, B.K. 1992: Agricultural chemistry consultant, Agricultural Chemistry Laboratory, MDIC Koronovia Research Station, Fiji - first report to 31 March 1992. DSIR Land Resources contract report; 92/20.

Dawson, M.I. 1991: Report on ploidy testing of *Agrostis* species. DSIR Land Resources contract report; 91/97a.

Dawson, M.I. 1991: Chromosome counts of *Agrostis castellana* cv 'Grasslands Milford'. DSIR Land Resources contract report; 91/97b.

Donnell, D.; Lee, R.; Daly, B.K.; Mew, G.; Willoughby, E.J. 1992: Data inter-relationships established from measurements in the National Soils Database. DSIR Land Resources technical record; 91. 268 p.

Druce, A.P. 1991: Indigenous higher plants of New Zealand. [Checklist]. 46 p.

Dymond, J.R. 1990: Percentage vegetation cover maps of Central Otago. DSIR Land Resources contract report; 90/10.

Dymond, J. 1991: Digital rectification of aerial and satellite imagery. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 3-9

Dymond, J.R.; Stephens, P.R.; Newsome, P.F.; Wilde, R.H. 1991: Mapping percentage vegetation cover using SPOT satellite data. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 18-21

Efford, M.G. 1991: Long-term studies of the dynamics of a local population of brushtail

possums, *Trichosurus vulpecula*; live trapping in the Orongorongo Valley in 1990/91. DSIR Land Resources technical record; 72. 28 p.

Efford, M.G. 1991: Use of age-specific population models to plan economic possum control. DSIR Land Resources contract report; 91/61.

Efford, M.G. 1991: Ecology, systematics and conservation of New Zealand's carnivorous landsnails. DSIR Land Resources contract report; 91/66.

Efford, M.G. 1992: User's manual for DDPoss : a PC program for density-dependent population projection : documentation for version IA, October 1991. DSIR Land Resources technical record; 71. 24 p.

Efford, M.G. 1992: User's manual for JS : a PC program for mark-recapture analysis. DSIR Land Resources technical record; 95. 17 p.

Efford, M.G. 1992: Long-term studies of the dynamics of a local population of brushtail possums, *Trichosurus vulpecula*; live trapping in the Orongorongo Valley in 1991/92. DSIR Land Resources technical record; 111. 26 p.

Efford, M.G. 1992: A stochastic model of the spread of bovine tuberculosis in a homogeneous possum population. DSIR Land Resources technical record; 121. 19 p.

Efford, M.G.; Bokeloh, D. 1991: Some results from a study of the land snail *Wainuia urnula* (Pulmonata: Rhytididae) and their implications for snail conservation. DSIR Land Resources contract report; 91/1.

Eyles, G.O. 1991: Cook Islands land use capability project. End-of-project report. DSIR Land Resources contract report; 90/26.

Eyles, G.O.; Harmsworth, G.R. 1991: Review on the application of DSIR Land Resources databases to Ministry for the Environment outcome areas. DSIR Land Resources contract report; 91/27.

Eyles, G.O.; Jessen, M.R. 1990: Summary of the Cook Is land use capability project. DSIR Land Resources contract report; 90/19.

Gibb, R.G. 1991: DSIR ARC/Manager a comprehensive menu system for managing sets of data coverages within pcARC/INFO. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 13-14

Giltrap, D.J. 1991: Terrain modelling and stereoscopic display. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 34

Giltrap, D.J. 1991: Report on advice/investigations database for the Parliamentary Commissioner for the Environment. DSIR Land Resources contract report; 91/23.

Given, D.R. 1991: Studies on threatened plants. Part 2. Autecological study of Chatham Island species. DSIR Land Resources contract report; 91/57.

Griffiths, E. 1991: Assessing permeability class from soil morphology. DSIR Land Resources technical record; 40. 48 p.

Griffiths, E. 1991: Investigation of trickle irrigation on two orchards on the Heretaunga Plains. DSIR Land Resources technical record; 65. 61 p.

Griffiths, E. 1991: Reduction of the impact of *Phytopthera* by cultural practices. Progress report for the New Zealand Apple and Pear Marketing Board. DSIR Land Resources contract report; 91/33.

Harmsworth, G.R. 1990: Land use capability extended legend of the Northland region - 2nd edition New Zealand Land Resource Inventory : to accompany the 2nd edtion 1:50 000 NZLRI worksheets. (Version 2.1). DSIR Land Resources technical record; 3 (Version 2.1.). 74 p.

Harmsworth, G.R. 1990: Physical resource classifications used for the Northland region - 2nd edition New Zealand Land Resource Inventory. DSIR Land Resources technical record; 4. 23 p.

Harmsworth, G.R. 1991: Stock carrying capacity and site index data for the Northland region - 2nd edition New Zealand Land Resource Inventory. DSIR Land Resources technical record; 5 (Version 2). 17 p.

Harmsworth, G.R. 1991: Stock carrying capacity and fertiliser data for the Northland region - 2nd edition New Zealand Land Resource Inventory. DSIR Land Resources technical record; 6 (Version 2). 33 p.

Harmsworth, G.R. 1991: Site index data of *Pinus radiata* for the Northland region - 2nd edition New Zealand Land Resource Inventory. DSIR Land Resources technical record; 7 (Version 2). 18 p.

Harmsworth, G.R.; Page, M.J. 1991: Correlation and description of land use capability units within the Bay of Plenty Regional Council area and eastern catchment boundary area. DSIR Land Resources contract report; 91/114.

Harris, W.; Decourtye, L. 1991: Observations on the effects of winter temperatures at three locations in France on New Zealand populations of *Leptospermum scoparium* (Myrtaceae) and related species. DSIR Land Resources technical record; 30. 33 p.

Harris, W.; Heenan, P.B. 1991: The connection between 'ti tawhiti', a Maori crop plant, and the ornamental cultivar *Cordyline* 'Thomas Kirk' : an account of all the evidence assembled in the course of investigating the links between an ornamental *Cordyline* cultivar of unknown origin and a crop plant of the Maori named either ti tawhiti, ti kowhiti or ti para. DSIR Land Resources technical record; 45. 16 p.

Hawley, J.G. 1990: Report on land suitability for residential development. DSIR Land Resources contract report; 90/18.

Hearfield, M.E. 1991: Rock wren ecology and population assessment. Part 1. DSIR Land Resources contract report; 91/44.

Heatherington, M. 1991: Generation of quality maps from raster and vector inputs. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 45-51

Hewitt, A.E. 1990: Supplement to the New Zealand Soil Classfication - version 2.0. Supplement to DSIR Land Resources technical record; DN 2. 9 p.

Hewitt, A.E. 1990: Soil characteristics in selected areas of the Dansey Ecological District. DSIR Land Resources technical record; DN 6. 60 p.

Hewitt, A.E. 1991: Soil assessment of the proposed Oamaru effluent disposal site. DSIR Land Resources contract report; 91/108.

Hewitt, A.E. 1992: Soil recconnaisance of selected areas of the Hawkdun Ecological District. DSIR Land Resources technical record; 99. 53 p.

Hewitt, A.E.; Fergusson, D.A. 1990: Soil features relevant to shallow mass movement in the Nine Mile Creek slide, Cromwell Gorge, Otago. DSIR Land Resources contract report; 90/8.

Hewitt, A.E.; McIntosh, P.D. 1991: Soils of the Pukeuri works farm and their suitability for effluent disposal. DSIR Land Resources contract report; 91/9.

Hicks, D.L. 1990: Landslide damage to hill country under pasture, pine plantation, scrub and bush, in Taranaki. DSIR Land Resources technical record; 31. 19 p.

Hicks, D.L. 1990: Long-term impact of erosion on hill country farm production. DSIR Land Resources technical record; 32. 11 p.

Hicks, D.L. 1990: Long-term impact of soil conservation on hill country farm production. DSIR Land Resources technical record; 33. 19 p.

Hicks, D.L. 1991: Effect of soil conservation tree plantings on damage sustained by the Whareama Catchment during the storm of 8-11 April 1991. DSIR Land Resources contract report; 91/106.

Hunt, J.L. 1991: X-ray fluorescence analysis of sulphur in rocks and soils. DSIR Land Resources technical record; 73. 12 p.

Hunter, G.G. 1992: Guidelines for assessing land use capability in South Island pastoral high country lands. DSIR Land Resources technical record; 115. 26 p. DSIR Land Resources, Lower Hutt.

Hunter, G.G.; Basher, L.R. 1991: Effects of sheep grazing in high rainfall, alpine tall tussock grassland. DSIR Land Resources contract report; 91/5.

Hunter, G.G.; Lynn, I.H. 1990: Storm-induced soil losses from South Canterbury and north Otago downlands. DSIR Land Resources technical record; 22. 7 p.

Jessen, M.R. 1990: Report on land suitability for residential development. DSIR Land Resources contract report; 90/17.

Jessen, M.R.; Page, M.J.; Wilde, R.H.; Miller, D.E.K. 1990: Land use capability of Atiu, Cook Islands - survey report and mapper's handbook. DSIR Land Resources contract report; 90/15.

Johnson, P.N. 1990: Shelton Downs, Lake Ohau : botanical report. DSIR Land Resources vegetation report; 705. 12 p.

Johnson, P.N. 1990: Kaikorai Estuary, Green Island tip : botanical report. DSIR Land Resources vegetation report; 706. i, 20 p.

Johnson, P.N. 1990: Lake Wakatipu aquatic vegetation : botanical report. DSIR Land Resources vegetation report; 753. 8 p.

Johnson, P.N. 1991: Trees on Otago Peninsula. DSIR Land Resources vegetation report; 755. 6 p.

Johnson, P.N. 1991: Kaikorai Estuary revegetation trial : progress report. DSIR Land Resources contract report; 91/10.

Johnson, P.N. 1991: Ahuriri Valley wetlands : botanical report. DSIR Land Resources contract report; 91/11.

Johnson, P.N. 1991: Tekapo kettleholes : Botanical report. DSIR Land Resources contract report; 91/12.

Johnson, P.N. 1991: Lake Monowai shore vegetation : botanical report. DSIR Land Resources contract report; 91/18.

Johnson, P.N. 1991: Kaikorai Estuary revegetation trial : second progress report. DSIR Land Resources contract report; 91/87.

Johnson, P.N. 1991: Yellow Head, Otago Harbour : botanical report. DSIR Land Resources contract report; 91/88.

Johnson, P.N. 1991: Highcliff–Boulder Beach, Otago Peninsula : report on aspects of vegetation management. DSIR Land Resources contract report; 91/102.

Johnson, P.N. 1991: Lake Waihola : report on botany of western swamp. DSIR Land Resources contract report; 91/104.

Johnson, P.N. 1991: Observation Point-Flagstaff Hill revegetation specification. DSIR Land Resources contract report; 91/111.

Johnson, P. 1991: Native bush conservation values, Turnbulls Bay, Otago Peninsula. DSIR Land Resources contract report; 91/113.

Johnson, P.N. 1991: Kaikorai Estuary revegetation trial : third progress report. DSIR Land Resources contract report; 91/117.

Johnson, P.N. 1992: Kaikorai Estuary revegetation trial : fourth progress report. DSIR Land Resources contract report; 92/26.

Johnson, P.N.; Hewitt, A.E. 1991: Flat Top Hill, Central Otago : report on soils and vegetation. DSIR Land Resources contract report; 91/103.

Karl, B.J. 1991: The ecology of the kereru or New Zealand Pigeon (*Hemiphaga novaeseelandiae*). Part 1. DSIR Land Resources contract report; 91/45.

Kelly, G.C. 1990: Anatoki (including Handcock Falls), 742.6 ha. DSIR Land Resources vegetation report; 712. 9 p.

Kelly, G.C. 1990: Dry River and Motupipi Cave, 90 +0.2 ha (also Manson Cave). DSIR Land Resources vegetation report; 713. 11 p.

Kelly, G.C. 1990: Grove, 3.5 ha. DSIR Land Resources vegetation report; 714. 7 p.

Kelly, G.C. 1990: Hanson Winter, 11.3 ha. DSIR Land Resources vegetation report; 715. 8 p.

Kelly, G.C. 1990: Payne's Ford, 58.2 ha. DSIR Land Resources vegetation report; 716. 8 p.

Kelly, G.C. 1990: Rameka Creek, 14.9 ha. DSIR Land Resources vegetation report; 717. 6 p.

Kelly, G.C. 1990: Takaka Hill, 432 ha. DSIR Land Resources vegetation report; 718. 10 p.

Kelly, G.C. 1990: Washbourn, 9.7 ha. DSIR Land Resources vegetation report; 719. 7 p.

Kelly, G.C. 1991: Aorere Caves, 51.9 ha. DSIR Land Resources vegetation report; 726. 9 p.

Kelly, G.C. 1991: Gouland Downs, 6564 ha. DSIR Land Resources vegetation report; 727. 7 p.

Kelly, G.C. 1991: Kaihoka Lakes, 44.7 ha. DSIR Land Resources vegetation report; 728. 9 p.

Kelly, G.C. 1991: Mangarakau, 145 ha. DSIR Land Resources vegetation report; 729. 7 p.

Kelly, G.C. 1991: West Haven, 81.5 ha. DSIR Land Resources vegetation report; 730. 7 p.

Kelly, G.C. 1991: Puponga Farm, c. 405 ha (and adjoining Crown Land). DSIR Land Resources vegetation report; 731. 14 p.

Kelly, G.C. 1991: Farewell Spit, 11 290 ha. DSIR Land Resources vegetation report; 732. 18 p.

Langham, N.P.E. 1991: The ecology of the kereru or New Zealand pigeon (*Hemiphaga novaeseelandiae*). Part 2. DSIR Land Resources contract report; 91/45.

Lee, W.G. 1990: Flowering of *Chionochloa* species in Takahe Valley, Fiordland, during the 1989-1990 summer. DSIR Land Resources vegetation report; 704. 7 p.

Lee, W.G. 1990: Monitoring *Chionochloa spiralis* in Takahe Valley, Fiordland. DSIR Land Resources vegetation report; 707. 16 p.

Lee, W.G. 1991: Eglinton Valley : botanical values in relation to sheep grazing. DSIR Land Resources contract report; 91/52.

Lee, W.G. 1991: Recovery index for snow tussock grassland. DSIR Land Resources contract report; 91/59.

Lee, W.G. 1992: Impact of fire and grazing on the ecology of narrow-leaved snow tussock in Otago : submission prepared on behalf of DoC. DSIR Land Resources contract report; 92/25.

Lee, W.R.; Johnson, P.N. 1990: Consideration of the impacts of grazing on Highcliff. DSIR Land Resources vegetation report; 754. 6 p.

Leslie, D.M. 1991: Spatial information research and development research in DSIR Land Resources. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 65-69

Luckman, P.G. 1991: Modelling for spatial interpretations and decision support in natural resource management : use of the hybrid expert system Nexpert OBJECT with the ARC/INFO GIS. DSIR Land Resources technical record; 46. 68 p.

Luckman, P.G.; Dymond, J.R. 1992: Implementing knowledge based image interpretation. DSIR Land Resources technical record 106. 26 p.

Luckman, P.G.; Gibb, R.G.; Heatherington, M. 1991: Integrating expert systems and GIS. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 56-64

Luckman, P.G.; Jessen, M.R.; Trangmar, B.B. 1992: Land evaluation systems for planning peri-urban land use in New Zealand. DSIR Land Resources technical record; 93. 31 p.

Luckman, P.G.; Thompson, R.C. 1990: Monitoring and evaluating the effectiveness of measures to control erosion in the Gisborne-East Cape region, New Zealand. Part 1. Description of site conditions and treatments. DSIR Land Resources technical record; 23. 27 p.

Luckman, P.G.; Thompson, R.C. 1990: Monitoring and evaluating the effectiveness of measures to control erosion in the Gisborne-East Cape region, New Zealand. Part 2. Knowledge-based systems. DSIR Land Resources technical record; 24. 29 p.

Luckman, P.G.; Thompson, R.C. 1990: Monitoring and evaluating the effectiveness of measures to control erosion in the Gisborne-East Cape region, New Zealand. Part 3. Effectiveness assessments. DSIR Land Resources technical record; 25. 64 p.

Luckman, P.G.; Thompson, R.C. 1991: Monitoring and evaluating the effectiveness of measures to control erosion in the Gisborne-East Cape region, New Zealand. Part 4. Description of knowledge-bases. DSIR Land Resources technical record; 47. 81 p.

Luckman, P.G.; Thompson, R.C. 1991: An assessment of soil conservation activities in the Manawatu-Wanganui region. DSIR Land Resources contract report; 91/8.

Lynn, I.H. 1990: Land classification on Glen Lee and Mt. Gladstone Runs. DSIR Land Resources contract report; 90/9.

Lynn, I.H. 1990: Land systems for upper Waimakiriri scenic corridor. DSIR Land Resources contract report; 90/11.

Lynn, I.H. 1991: New Zealand Land Resource Inventory Marlborough Region, land use

capability extended legend (version 2.2 1991). DSIR Land Resources technical record; 66. 216 p.

Lynn, I.H.; Hewit, A.E. 1990: Land systems for the Integrated Rabbit and Land Management Programme. DSIR Land Resources contract report; 90/13.

McDonald, W.S. 1991: Database integration. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 54-55

McDonald, W.S. 1991: Datatrieve definitions for the soil description handbook. DSIR Land Resources. DSIR Land Resources technical record; 55. [111 p.]

McDonald, W.S.; Giltrap, D.J.; Jansen, M.T. 1991: Land resource data tools for spatial interpretations. DSIR Land Resources technical record; 63. 13 p.

McDonald, W.S.; van der Raaij, M.T. 1992: Defining soil data spatial limitations. DSIR Land Resources technical record; 80. 16 p.

McGlone, M.S. 1990: The early Holocene as an analogue for a 2 x CO_2 New Zealand. Report to the Ministry for the Environment. DSIR Land Resources vegetation report; 757. 52 p.

McIntosh, P.D. 1990: Soils of Redbank Research Station, Clyde. DSIR Land Resources technical record; 21. 60 p.

McIntosh, P.D. 1991: Site assessment for South Wood Export eucalypt plantations in Southland DSIR Land Resources contract report; 91/116.

McIntosh, P.D.; Allen, R.B. 1990: Preliminary assessment of six sites in Otago and Southland for narcissi, lily, garlic and zantedeschia bulb production. DSIR Land Resources technical record; DN 1. 42 p.

McIntosh, P.D.; Beecroft, F.G.; Patrick, B.H. 1992: Register of saline soil sites in north and central Otago. Volume 2. DSIR Land Resources technical record; 82. 59 p.

McLennan, J.A. 1991: Kiwi recovery plan : technical draft. DSIR Land Resources contract report; 91/7.

McLennan, J.A. 1991: Ecology of great spotted kiwi, *Apteryx haastii*. DSIR Land Resources contract report; 91/48.

McLeod, M. 1991: Topsoil pugging study on the Hauraki Plains. DSIR Land Resources technical record; 62. 12 p.

McLeod, M. 1992: Soil information sheets for the proposed Te Kawa Irrigation Area, North Island, New Zealand. DSIR Land Resources technical record; 75. 61 p.

McLeod, M. 1992: Soil taxonomic unit descriptions for the proposed Te Kawa Irrigation Area, North Island, New Zealand. DSIR Land Resources technical record; 76. 53 p.

McQueen, D.J. 1991: Environmental impact of recreational use on DoC estate. Part 1. Guidelines on track location management and repair. DSIR Land Resources contract report; 91/54.

McQueen, D.J.; Wales, J.F.; Barker, P.R.; Lilley, G.P.; Hayes, M. 1991: Sustainable forestry soil compaction trial, year one 1990-91. DSIR Land Resources technical record; 70. 70 p.

McQueen, D.J.; Williams, P.A.; Lilley, G.P. 1991: Environmental impact of recreational use on DoC estate. Part 2. Effects of camping. DSIR Land Resources contract report; 91/54.

Meads, M.J. 1991: Threatened weta recovery plan. DSIR Land Resources contract report; 90/25.

Meads, M.J.; Notman, P.R. 1991: A survey of the giant wetas (*Deinacrida parva* and *Deinacrida* sp.) in the north branch of the Hapuku River, Kaikoura, 29 April-3 May 1991. DSIR Land Resources technical record; 43. 34 p.

Meads, M.J.; Notman, P.R. 1991: Giant weta status and conservation. DSIR Land Resources contract report; 91/46.

Meads, M.J.; Notman, P.R. 1992: Survey of the status of three species of giant wetas (*Deinacrida*) on the Seaward and Inner Kaikoura Ranges. DSIR Land Resources technical record; 89. 35 p.

Meads, M.J.; Notman, P. 1992: Resurvey for giant wetas (*Deinacrida rugosa*) released on Maud Island, Marlborough Sounds. DSIR Land Resources technical record; 90. 30 p.

Meurk, C.D. 1990: Inanga spawning habitat on the West Coast, South Island. DSIR Land Resources vegetation report; 709. i, 25 p.

Meurk, C.D. 1991: Campbell Island vegetation monitoring. DSIR Land Resources technical record; 52. 3 p.

Meurk, C.D. 1991: Assessment and management options for several wetland patches along the Christchurch–Akaroa highway. DSIR Land Resources contract report; 91/24.

Meurk, C.D. 1991: Notes on the native plants of the Christchurch river banks and their management. DSIR Land Resources contract report; 91/32.

Meurk, C.D. 1991: Assessing privately owned unprotected beech forests in mid Canterbury. DSIR Land Resources contract report; 91/38.

Meurk, C.D. 1991: Assessment of lowland beech forest at "Pine Hill", Staveley. DSIR Land Resources contract report; 91/40.

Meurk, C.D. 1991: MacKenzie Basin tussock management. DSIR Land Resources contract report; 91/63.

Meurk, C.D. 1991: Restoration proposal for Round Hill Gold Mine, North Otago. DSIR Land Resources contract report; 91/79.

Meurk, C.D. 1991: Plan for establishing native plant communities along a stream bank, St Anne's School, Christchurch. DSIR Land Resources contract report; 91/80a.

Meurk, C.D. 1992: Assessment of botanical values and management options for wetlands at the

Styx River mouth. DSIR Land Resources contract report; 92/17.

Meurk, C.D. 1992: Concept plan for Te Mau Mahara (the living memorial) at Wilsons Swamp (Otukaikino). DSIR Land Resources contract report; 92/19.

Meurk, C.D.; Buxton, R.P. 1991: A New Zealand register of permanent vegetation plots. DSIR Land Resources contract report; 91/35.

Meurk, C.D.; Webb, T.H. 1991: Comments on options for an access road to the Mt Cavendish gondola construction site. DSIR Land Resources contract report; 91/80.

Mew, G.; Newsome, P.F.J.; Giltrap, D.J.; Willoughby, E.J. 1991: CONFIDENTIAL. DSIR Land Resources contract report ; 91/115.

Mew, G.; Rowse, M.L. 1992: Guidelines for the preparation, production and maintenance of maps. DSIR Land Resources technical record ; 84. 27 p.

Miller, D.E.K. 1990: Erosion control handbook, Atiu, Cook Islands. DSIR Land Resources contract report ; 90/16.

Moller, H.; Beggs, J.R.; Tilley, J.A.V.; Toft, R.J.; Wilson, N.J.; Alspach, P.A. 1991: Ecology and control of wasp populations in New Zealand. DSIR Land Resources contract report ; 90/29.

Molloy, B.P.J. 1990: Enrichment of rare plants, Enys and Castle Hill Reserves. DSIR Land Resources vegetation report ; 703. 72 p.

Molloy, B.P.J. 1991: Notes on the rare sedge, Carex *inopinata*, with particular reference to the Kowhai Point Recreation Reserve, Marlborough Land District. DSIR Land Resources vegetation report ; 735. i, 9 p.

Molloy, B.P.J. 1992: Little Motuariki Island RAP, Lake Tekapo : botanical assessment. DSIR Land Resources vegetation report ; 737. 14 p.

Newsome, P.F.J. 1991: The national GIS database. In: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record ; 59. p. 52-53

Orchard, V.A. 1991: Report on microbial activity and biomass in relation to fungicide degradation. DSIR Land Resources technical record ; 35. 31 p.

Orchard, V.A.; Speir, T.W. 1990: Evaluation of biological products. DSIR Land Resources contract report ; 90/1.

Orchard, V.A.; Theng, B.K.G.; Searle, P.L.; Burke, C.M.; Parfitt, R.L.; Donnell, D.; Harper, S. 1991: Interim report on DDT residues in soil and experiments to enhance their degradation rates. DSIR Land Resources technical record ; 58. 35, [5] p.

Page, M.J. 1990: Land use capability extended legend of the Wellington region. 2nd edition. New Zealand Land Resource Inventory. To accompany the 2nd edition 1:50 000 NZLRI. DSIR Land Resources technical record ; 26 (version 2.0). 55 p.

Page, M.J. 1992: Physical resource classifications used in the Wellington region. 2nd edition. New Zealand Land Resource Inventory. DSIR Land Resources technical record ; 112. 21 p.

Page, M.J.; Jessen, M.R. 1990: Summary of the Cook Islands land use capability project - for the people of Atiu. DSIR Land Resources contract report ; 90/22.

Parfitt, R.L. 1990: Ions in soil solution affecting apple nutrition on Mapua soils. DSIR Land Resources technical record ; 14. 27 p.

Parfitt, R.L. 1991: Regressions of toxic aluminium level (KCl-Al) against pH, clay, and clay mineral content of soils. DSIR Land Resources technical record ; 9. 15, [15] p.

Parfitt, R.L. 1991: Ions in soil solution affecting kiwifruit nutrition on Te Puke soils. DSIR Land Resources technical record ; 78. 42 p.

Parfitt, R.L. 1992: Irrigation and fertigation of apple trees on Mapua soil 1990-1991. DSIR Land Resources technical record ; 83. 20 p.

Partridge, T.R. 1991: The interaction between pingao and marram on sand dunes. DSIR Land Resources contract report ; 91/65.

Partridge, T.R. 1992: An assessment of revegetation of spoil heaps at the Christchurch City rubbish disposal site. DSIR Land Resources contract report ; 92/16.

Percival, H.J. 1990: Procedures for the extraction and chemical analysis of soil solutions. DSIR Land Resources technical record ; 10. 42 p.

Percival, H.J. 1990: Computer procedures for the tabulation and speciation of soil solution constituents. DSIR Land Resources technical record ; 11. 29 p.

Percival, H.J. 1991: Review of data on aluminium in water and soils of Bluff Hill. DSIR Land Resources contract report ; 90/27.

Percival, H.J.; McIntosh, P.D. 1992: Characterisation of soil waters and leachates from selected soils on Bluff Hill and at Omaui. DSIR Land Resources contract report ; 92/24.

Porter, D.; McLennan, J.A.; Cowan, P.E. 1991: Deterrent compounds to prevent non-target animals from eating poisonous baits laid for possums. DSIR Land Resources contract report ; 91/42.

Ross, C.W. 1991: Peer review of land rehabilitation, Martha Hill mining project. DSIR Land Resources contract report ; 91/26.

Ross, C.W. 1991: Peer review of land rehabilitation, Golden Cross Mine. DSIR Land Resources contract report ; 91/94.

Ross, C.W.; Barker, P.R. 1991: Report on benchmark data for topsoil monitoring at a proposed commercial turf farm, Judgeford, Wellington. DSIR Land Resources contract report ; 90/24.

Ross, C.W.; Barker, P.R. 1991: First monitoring

report on effects of turf farming at Judgeford. DSIR Land Resources contract report ; 91/37.

Ross, C.W.; Hunt, W. 1991: Land restoration plans, Fraser Shingle Ltd : alternate gravel resource area, Fernhill, Hastings. DSIR Land Resources contract report ; 91/15.

Ross, C.W.; Mew, G. 1990: CONFIDENTIAL. DSIR Land Resources contract report ; 90/7.

Ross, C.W.; Mew, G. 1991: Land rehabilitation to indigenous forest species after mining : soil studies (Giles Creek coal mine, Reefton, Westland). DSIR Land Resources contract report ; 91/49.

Rudge, M.R.; August, J.A.; Webb, I.W. 1991: Review of DSIR Land Resources radio-laboratory, "Sirtrack". DSIR Land Resources contract report ; 91/91.

Ruru, H.W.; Claydon, J.J. 1991: Balance calibration procedures. DSIR Land Resources technical record ; 16. 34 p.

Russell, P.C.; Webb, C.J. 1990: Preparation of publications and other documents. DSIR Land Resources technical record ; 1. 23 p.

Scheele, S. 1990: Inter-institutional Linkages Programme : First Expert Meeting : Jakarta, Indonesia, 30 October-2 November 1990 : Project 1, Cultural information exchanges in ethnobotany. DSIR Land Resources, Havelock North. 20 p.

Shepherd, T.G. 1991: Towards sustainable soil and crop management of arable land. DSIR Land Resources technical record ; 56. 20 p.

Shepherd, T.G.; McKay, A.D.; Costall, D.A.; Gray, Y.S. 1991: Inventory of the soils and pastures of the Waikakariki Farm, Mangatu Blocks, Gisborne. DSIR Land Resources contract report ; 91/5.

Singleton, P.L. 1992: Soil map unit descriptions for Ruakura Agricultural Centre, Hamilton, North Island, New Zealand. Supplement to DSIR Land Resources soil map ; 304/1. DSIR Land Resources technical record ; 88. 88 p.

Singleton, P.L.; McLeod, M. 1991: Soils in proposed Beachlands/Maraetai effluent disposal scheme. DSIR Land Resources contract report ; 91/3.

Singleton, P.L.; Ratukalou, I.; Maudsley, D. 1990: The pattern of water extraction by grapes on two soils in the Waikato. DSIR Land Resources technical record ; 13. 30 p.

Singleton, P.L.; Speir, T.W. 1992: Irrigation with leachate onto soils at Whitford. DSIR Land Resources contract report ; 92/2.

Singleton, P.L.; Widdowson, J.P. 1991: Chemical properties of overburden from proposed rehabilitation area, Kopuku. DSIR Land Resources contract report ; 91/118.

Smith, S.M. 1991: Soil evaluation of proposed retirement village, Wigram Road. DSIR Land Resources contract report ; 91/30.

Smith, S.M.; Trangmar, B.B. 1991: Integrating crop modelling, land evaluation and geographic information systems. *In:* Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record ; 59. p. 32

Sparling, G.P.; Hart, P.B.S.; Feltham, C.W.; August, J.A.; Searle, P.L. 1991: Simple methods to produce dual-labelled (^{14}C and ^{15}N) ryegrass and to estimate ^{14}C in soils, plants and microbial biomass. DSIR Land Resources technical record ; 77. 21, [4] p.

Speir, T.W.; August, J.A. 1992: Production of Biosoil Loam using sewage sludge : interim report to Wellington City Council (28 November 1991-12 January 1992). DSIR Land Resources contract report ; 92/1.

Speir, T.W.; Burke, C.M.; Hart, P.B.S. 1990: Development and evaluation of bark-based organic potting mixes. DSIR Land Resources contract report ; 90/12.

Spurr, E.B.; Moller, H.; Harris, R.J. 1991: Selection of baits for poisoning wasps. DSIR Land Resources contract report ; 91/17.

Stephens, P.R. 1990: Use of remote sensing for land management. DSIR Land Resources contract report ; 90/3.

Stephens, P.; Thompson, S. 1991: Forest inventory and resurvey using satellite data. *In:* Stephens, P.R.; White, M.F. Proceedings of workshop : remote sensing and geographic information systems for natural resource management. DSIR Land Resources technical record ; 59. p. 35-37

Stephens, P.R.; White, M.F. 1991: Proceedings of workshop : remote sensing and geographic information systems for natural resource management. DSIR Land Resources technical record ; 59. 69, [8] p.

Stephens, P.R.; White, M.F. 1992: NOAA Weather Satellite data for mapping and monitoring the New Zealand landscape : results of an inital investigation. DSIR Land Resources techncial record ; 29. 22 p.

Stephens, P.R.; Wilde, R.H. 1992: Remote sensing : geographic information system land evaluation and use capability for dryland farming within the Planning and Budget Department, Ministry of Agriculture, Islamic Republic of Iran. DSIR Land Resources contract report ; 92/7.

Stephenson, W.R. 1990: EIGAXI.PAS : a computer program to quantify the shear resonance of axisymmetric basins of soft soil. DSIR Land Resources technical record ; 17. 43 p.

Stephenson, W.R. 1991: Predicted response of Pukehou seismic test site. DSIR Land Resources technical record ; 27. 14 p.

Stephenson, W.R. 1992: SOFTSOIL.PAS - a computer program which evaluates the importance of site effects in modifying earthquake damage. DSIR Land Resources technical record ; 87. 37 p.

Stephenson, W.R.; Barker, P.R. 1992: Wellington

Regional Council regional natural disaster reduction plan : seismic hazard. Report on cone penetrometer and seismic cone penetrometer probing in Wellington City, Kapiti Coast and Upper Hutt Valley (part 4.2 of 1991 study). DSIR Land Resources contract report ; 92/14.

Stephenson, W.R.; Barker, P.R.; Mew, G. 1990: Wellington Regional Council regional natural disaster reduction plan : seismic hazard. DSIR Land Resources contract report ; 90/5.

Sykes, W.R. 1990: Survey of conifers. DSIR Land Resources vegetation report ; 710. i, 6 p.

Sykes, W.R. 1990: Kermadec Islands expedition - August 1990. DSIR Land Resources vegetation report ; 711a. 12 p.

Tate, K.R.; Newsome, P.F. 1991: Carbon reserves in New Zealand's marginal lands. DSIR Land Resources contract report ; 91/69.

Thomas, B.W.; Taylor, R.H. 1991: The possibilities for eradication of rats from Kapiti Island. DSIR Land Resources technical record ; 60. 11 p.

Theng, B.K.G. 1990: Inorganic and organic soil colloids : properties and interactions : lectures in China, May-June 1988. DSIR Land Resources technical record ; 2. 129 p.

Theng, B.K.G.; Claydon, J.J.; Daly, B.K.; Giddens, K.M.; McQueen, D.J. 1991: Soil analysis for landfill lining material. DSIR Land Resources contract report ; 91/76.

Theng, B.K.G.; Claydon, J.J.; Giddens, K.M. 1991: Analysis of soil for landfill lining material. DSIR Land Resources contract report ; 91/86.

Thompson, R.C. 1992: Evaluating similarity of erosion sites. DSIR Land Resources technical record ; 107. 20 p.

Thompson, R.C.; Luckman, P.G. 1991: Monitoring and evaluating the effectiveness of measures to control erosion in the Gisborne-East Cape region, New Zealand. Part 5. Empirical guidelines for erosion control. DSIR Land Resources technical record ; 48. 13, [24] leaves.

Thompson, R.C.; Luckman, P.G. 1992: Performance of biological erosion control in soft rock terrain, and implications for silvopastoral systems. DSIR Land Resources technical record ; 94. 22 p.

Trangmar, B.B.; Bastiaansen, A.M.P.; Cazaux, G.L.; Verheye, W.H. 1991: Project document : rural sector land use planning, Mozambique. UNDP/FAO consultancy report.

Trangmar, B.B.; Bastiaansen, A.M.P.; Cazaux, G.L.; Verheye, W.H. 1991: Report of the project formulation mission : Mozambique land and water resources evaluation for land use planning. UNDP/FAO consultancy report.

Trangmar, B.B.; Goldsmith, P.F.; Motsete, M. 1990: Botswana soil mapping and advisory services project BOT/85/011 : report of the tripartite evaluation mission.

Trangmar, B.B.; Jessen, M.R. 1991: Crop suitability ratings, Atiu, Cook Islands. DSIR Land Resources contract report; 90/23.

Trotter, C.M. 1991: Mapping possum damage to indigenous forest using remote sensing : a feasibility study. DSIR Land Resources contract report; 91/60.

Trotter, C.M. 1991: Landslide damage assessment using remotely sensed and geographic information system data. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 15-17

Trotter, C.M. 1991: Aerial video for disaster monitoring : a review of available imaging systems. DSIR Land Resources technical record; 61. 20 leaves

Trustrum, N.A.; Lambert, M.G.; Costall, D.A.; Foote, A.G. 1991: Revegetation of erosion scars in Wairarapa hill country. DSIR Land Resources contract report; 91/109.

Vincent, K.W. 1991: Record of soil inspection and installation of tensiometer tubes at Heywood Orchards Ltd, Dehra Doon Road, Motueka. DSIR Land Resources contract report; 91/70.

Vincent, K.W. 1991: Soil pattern and characteristics, Fuji Trial Block, Appleby Research Orchard, Nelson. DSIR Land Resources contract report; 91/71.

Vincent, K.W. 1991: The soil pattern at the MAFTech/Marlborough Research Centre dryland pasture trial, Awatere Valley, Marlborough. DSIR Land Resources contract report; 91/72.

Vincent, K.W. 1991: Soils of the Marlborough Research Centre trial farms at Rowley Crescent and Spring Creek. DSIR Land Resources contract report; 91/78.

Vincent, K.W. 1992: Soil characteristics near the southern urban boundary, Whither Hills, Blenheim. DSIR Land Resources contract report; 92/6.

Vincent, K.W. 1992: Soil water extraction of grapevines in two deep soils of the Wairau Plains, Marlborough. DSIR Land Resources technical record; 114. 50 p.

Waddington, D.C. 1990: The sparrow problem. DSIR Land Resources contract report; 90/21.

Walls, G.Y.; Scheele, S. 1990: The critical edge : forest margins of the Chatham Islands. DSIR Land Resources vegetation report; 711. 38 p.

Ward, R.D.; Hayes, M.J. 1991: Measurement of near-saturated hydraulic conductivity of undisturbed cores by use of the permeameter tube. DSIR Land Resources technical record; 20. 6 p.

Wardle, P. 1990: Vegetation changes in exclosure and control plots, Karangarua Valley, south

Westland. DSIR Land Resources technical record; 54. 8, [20] leaves.

Wardle, P.; Buxton, R.P. 1991: Monitoring the impact of grazing animals on DoC leases in south Westland. DSIR Land Resources contract report; 91/47.

Wardle, P.; Coleman, M.C. 1990: Climatic warming and the upper limits of four native forest trees. DSIR Land Resources vegetation report; 708. 70 p.

Watt, J.P.C.; Beecroft, F.G.; Vincent, K.W.; Ward, R.D. 1992: A field appreciation of three techniques for evaluating saturated hydraulic conductivity below a water table. DSIR Land Resources technical record; 104. 32 p.

Watt, J.P.C.; Burgham, S. 1992: Physical properties of eight soils of the Lincoln area, Canterbury. Derived data and hydraulic character statements. DSIR Land Resources technical record; 103. 134 p.

Watt, J.P.C.; Vincent, K.W. 1991: Physical properties of six soils of the Blenheim area : derived data hydraulic character statements. DSIR Land Resources technical record; 42. 121 p.

Watt, J.P.C.; Vincent, K.W. 1992: Tomato root distribution. DSIR Land Resources contract report; 92/28.

Webb, T.H. 1991: Land resource evaluation of proposed rural residential zone, Waikuku. scheme change 20. DSIR Land Resources contract report; 91/96.

Webb, T.H.; Smith, S.M.; Trangmar, B.B. 1991: Land resource evaluation of Christchurch City. DSIR Land Resources contract report; 91/4.

West, C.J. 1991: Literature review of the biology of *Clematis vitalba* (old man's beard). DSIR Land Resources vegetation report; 725. 37 p.

West, C.J. 1992: Ecological studies of *Clematis vitalba* (old man's beard) in New Zealand. DSIR Land Resources vegetation report; 736. iii, 146 p.

Whitehead, N.E.; Hunt, J.L.; Leslie, D.M.; Rankin, P.C. 1991: Determination of radioactivity and element concentration in soils from Niue Island. DSIR Land Resources technical record; 57. 58 p.

Whitehouse, I.E. 1990: Preliminary technical investigation of some environmental factors, Hopai and Elie Bays, Marlborough Sounds. DSIR Land Resources contract report; 90/6.

Whitehouse, I.E. 1991: Study brief for sedimentation and erosion investigation in Avon-Heathcote catchment. DSIR Land Resources contract report; 91/39.

Whitehouse, I.E.; Basher, L.R.; Tonkin, P.J. 1990: A landform classification for PNA surveys in eastern Southern Alps. DSIR Land Resources technical record; 19. 32 p.

Widdowson, J.P. 1991: The rehabilitation trial at Golden Cross. DSIR Land Resources contract report; 91/93.

Widdowson, J.P. 1992: Soil fertility and nutrient content of pasture on rehabilitation trial at Golden Cross. DSIR Land Resources contract report; 92/8.

Wilde, R.H. 1991: Time sequential study of land cover classes in the Manawatu sand country : vegetation and bareground changes from historical aerial photos and satellite imagery. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 38-44

Wilde, R.H.; Dymond, J.R.; Stephens, P.R.; Newsome, P.F.; White, M.F. 1991: Percentage bare ground as an indicator of broad soil class in the Mackenzie Basin. *In*: Stephens, P.R.; White, M.F. Proceedings of Workshop : Remote Sensing and Geographic Information Systems for Natural Resource Management. DSIR Land Resources technical record; 59. p. 22-31

Wilde, R.H.; Shepherd, T.G. 1990: Soil investigation for irrigation of the Mangatu blocks kiwifruit orchard, Waihirere, Gisborne. DSIR Land Resources contract report; 90/14.

Williams, P.A. 1990: The habitat of the rare herb *Scutellaria novae-zelandiae* and implications for its conservation. DSIR Land Resources vegetation report; 720. 9 p.

Williams, P.A. 1991: Habitat description of rock wren, western Nelson. Part 2. DSIR Land Resources contract report; 91/44.

Williams, P.A. 1991: Studies on threatened plants. Part 3. Ecology of the endangered herb, *Scutellaria novae-zelandiae*. DSIR Land Resources contract report; 91/57.

Wilson, P.R.; Toft, R.J.; Shepard, C.; Beggs, J.R. 1991: Will supplementary feeding of South Island kaka improve breeding success? DSIR Land Resources contract report; 91/55.

Yeates, G.W. 1991: Earthworms in New Zealand : an introductory bibliography. DSIR Land Resources technical record; 68. 19 p.

Yeates, G.W. 1992: Consolidated list of nematode samples collected at DSIR, Lower Hutt 1970-1992. DSIR Land Resources technical record; 98. 144 p.

Yeates, G.W.; van Etteger, M. 1991: Influence of sampling and extraction techniques on *Criconemoides* (Nematoda : Tylenchida) population estimates in forest litter. DSIR Land Resources technical record; 39. 6 p.

Yeates, G.W.; van Etteger, M. 1991: Morphometrics of developmental stages of four Dorylaimida (Nematoda). DSIR Land Resources technical record; 38. 11 p.

Yeates, G.W.; Risk, W.H. 1991: Effect of clover cyst nematode (*Heterodera trifolii*) on white clover production in Southland. DSIR Land Resources technical record; 37. 19 p.